VOL. 37, NO. 4. OCTOBER 1960

TROPICAL AGRICULTURE

THE JOURNAL OF THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE
(FACULTY OF AGRICULTURE, UNIVERSITY COLLEGE OF THE WEST INDIES)

CONTENTS

		Page
Editorial	.. ..	255
H. J. Gooding	*Yields of West Indian Maize*	257
J. S. Campbell and G. E. Hodnett	*Spacing Experiments with Dwarf Beans* (Phaseolus vulgaris *L.*) *in Trinidad*	265
S. A. Adeniyi and P. N. Wilson	*Studies on Pangola Grass at I.C.T.A., Trinidad—I.* ..	271
E. C. B. Langfield and J. J. Basinski	*The Effect of Time of Planting on Behaviour of Rice Varieties in Northern Australia*	283
G. Montsma	*Observations of Milk Yield, and Calf Growth and Conversion Rate, on Three Types of Cattle in Ghana* ..	293
N. H. Monteith	*Agricultural Extension Work among the Cane Growers of Fiji*	303
F. T. Last	*Incidence of* Striga hermonthica (*Del.*) *Benth. on Two Varieties of Irrigated Sorghum Differently Manured, Spaced and Thinned*	309
P. D. Turner and A. L. Wharton	*Leaf and Stem Infections of* Theobroma cacao *L. in West Africa, Caused by* Phytophthora palmivora (*Butl.*) *Butl.*	321
D. Price	*The Effects of Several Spray Régimes on Banana Fruit Weights*	325
Book Reviews	.. ..	329
Recent Publications	.. ..	340

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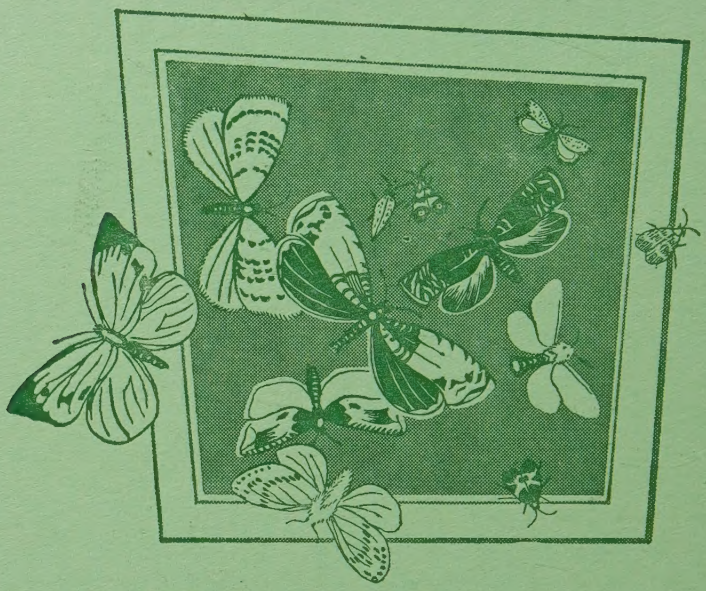

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Editorial

The merger of the Imperial College of Tropical Agriculture with the University College of the West Indies, to become its faculty of agriculture, took place on 1 August 1960. As we have already announced, this will not affect the general policy of this Journal. The authorities of the University College are happy that it should continue to provide a forum for research throughout the tropics, though much of our material will come as before from the Caribbean countries.

We have also to announce that from January 1961 the subscription for *Tropical Agriculture* will be increased to £2 10*s* 0*d* per annum, or 12*s* 6*d* per copy. This has nothing at all to do with the merger, but is forced upon us by an increase in the cost of publication. Since 1954 this journal has held its price steady, during a period in which costs were constantly rising and many comparable journals had to raise their subscription rates. Our present relatively modest increase is therefore an inevitable but not, we hope, too great a hardship for our readers.

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Yields of West Indian Maize

H. J. Gooding

Regional Research Centre, Imperial College of Tropical Agriculture, Trinidad, W.I.

The population of Trinidad is predominantly rice eating but data presented by Reed (1954) and Purseglove (1936) on import and local production, indicate that maize is of considerable importance in the island's economy. In Barbados and St Vincent maize is used to a greater extent for human consumption than in Trinidad, but the emphasis there as here is on the need for livestock feed. In St Vincent the lack of adequate supplies of locally produced maize partly contributed to the closing of a bacon factory which operated there.

The value of increasing the production of maize has been recognized in all these islands and Jamaica. In Trinidad in 1940 doubled tariffs on maize imports were proposed to encourage local production. The inability to meet the island's demand for locally grown maize is partly due to the unavailability of high yielding adapted varieties coupled with poor practices in the farming districts.

Various methods of breeding have been employed by graduate students at the I.C.T.A. in an attempt to produce adapted maize varieties for Trinidad. The end result, I.C.T.A. ' Farm Corn ', was obtained largely through mass selection. This is a tall, vigorous strain, relatively high yielding, mainly dent and of mixed yellow and orange endosperm. Jones (1932), Purseglove (1936) and Harper (1938) tried hybridization methods but subsequently the programmes were discontinued. Brown (1953) brought a renewed interest in maize breeding and work by Agble (1955), followed by McQuistan (1956), involved attempts at improving ' Farm Corn '.

Agble adopted long and short term programmes for developing superior strains, both involving a certain amount of inbreeding. He established (*a*) an F_1 top cross synthetic and also (*b*) a synthetic from S_2s of Brown's races. The latter were inferior. The reciprocal top crosses with ' Farm Corn ' were more uniform and less liable to lodging than ' Farm Corn ' itself. The performances of the races in top crosses were as follows: Cylindrical Dent × ' Farm Corn ' and West Indian Semi Dent × ' Farm Corn ' were good at two planting dates, the former being slightly higher yielding; Cuban Flint × ' Farm Corn ' showed extreme differences at early and late planting but the yield at the first planting date was the highest among all selections.

In Agble's classification of selections for combining ability with ' Farm Corn ' in reciprocal crosses, as indicated by visual characters of F_1 ears, Cuban Flint was good in both cases, West Indian Semi Dent and Cylindrical Dent were good in one case while Maïs Chandelle and St Croix Long Ear were fair in both cases. Haitian Yellow, Coastal Tropical Flint and Early Caribbean were classified as poor.

In 1955–56 McQuistan noted that he intended to follow the lines of work outlined by DEL VALLE (1949), that is to produce a synthetic based on S_1 lines. He self-pollinated a number of desirable ears on several races and made crosses between individual S_1 plants and 'Farm Corn'. The writer was given these seeds in October 1956 together with some open pollinated West Indian maize races. As a matter of policy it was decided not to commence a maize breeding programme but, having top cross seeds and maize races, it seemed desirable to compare their yields in Trinidad. Following a request for seed from Barbados, and as the local yields there were so low, the races and top crosses were also tested in that island.

Four yield trials were carried out and are reported here. Trials A and B were sown in November 1956 whilst trial C was sown in July and harvested in the *petit carême*. (The *petit carême* is the short undependable dry period usually occurring in September.) The period for trial C is one which is usually unsuitable to 'Farm Corn' as it appears to result in increased lodging and poor ear development.

EXPERIMENTAL RESULTS

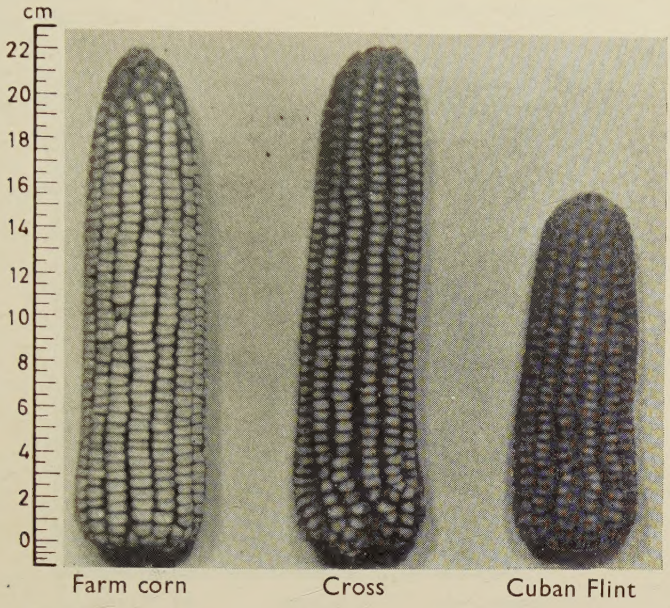
In trial A six top crosses were separately compared in two replications with 'Farm Corn' and with the race from which the parental S_1 was derived, namely Cylindrical Dent, West Indian Semi Dent, St Croix Long Ear, Maïs Chandelle, Haitian Yellow and Cuban Flint. In each plot there were two rows of top cross and one of each of the parents. The trial was thinned to sixteen single plant hills per sub-plot a few weeks after germination.

Table 1. Trial A. Mean yield of sun-dried grain in pounds per acre
Sown 2/11/56 Harvested 22/2/57

Description	*Mean*	*Cylindrical Dent*	*St Croix Long Ear*	*West Indian Semi Dent*	*Maïs Chandelle*	*Haitian Yellow*	*Cuban Flint*
'Farm Corn'	2 659	2 006 (24)	2 401 (24)	2 917 (28)	2 750 (29)	3 208 (26)	2 670 (23)
Race	1 692	1 382 (23)	1 705 (22)	1 881 (25)	1 412 (20)	1 414 (21)	2 359 (29)
Top cross	2 910	1 939 (51)	2 444 (57)	2 868 (52)	3 054 (58)	3 113 (50)	4 043 (62)
Differences	*S.E.*						
Race–'Farm Corn'	±602·3	−624	−696	−1 036	−1 338	−1 794	− 311
Top cross–'Farm Corn'	±521·7	− 67	+ 43	− 49	+ 304	− 95	+1 373
Top cross–Race	±521·7	+557	+739	+ 987	+1 642	+1 699	+1 684

NOTE: The numbers in parentheses are the numbers of plants on which the means are based.
Standard Errors Whole plots ±271·4 or 10·7 per cent (5 d.f.).
Sub-plots ±602·3 or 23·7 per cent (24 d.f.).
Plot size Whole plots 4 yards ×8 yards.
Spacing Rows 1 yard apart, hills 1ft 6in. in the rows.

All the Caribbean races were outyielded by 'Farm Corn' (*Table 1*), and partly because its yields were conspicuously variable between comparisons the yield differences have been shown for greater clarity. Only Haitian Yellow and Maïs Chandelle were significantly lower yielding than 'Farm Corn' (L.S.D.$=2{\cdot}064\times602{\cdot}3=1\,243{\cdot}1$ at the 5 per cent level). Of the top crosses, that with Cuban Flint was outstandingly superior as noted by AGBLE (1955), ($t=1\,373\div521{\cdot}7=2{\cdot}63$, whilst t at 24 d.f.$=2{\cdot}064$). The Cuban Flint top cross, however, was only just significantly superior to Maïs Chandelle top cross.



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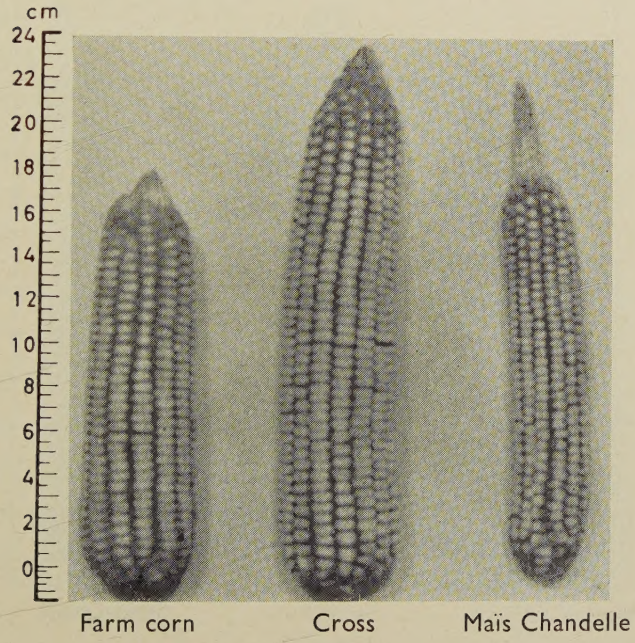

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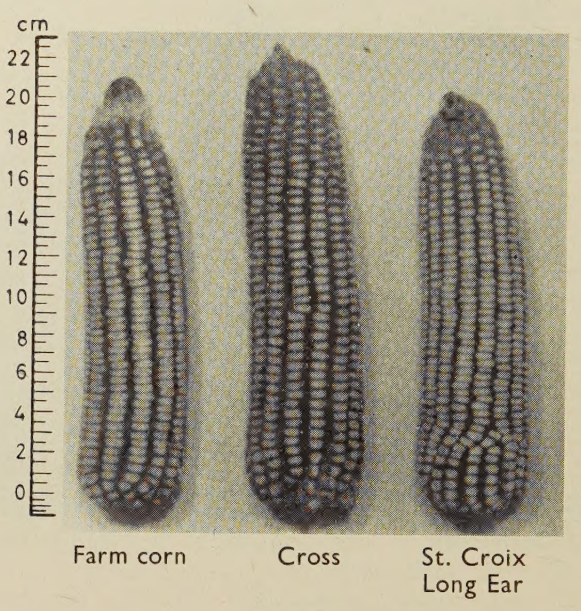

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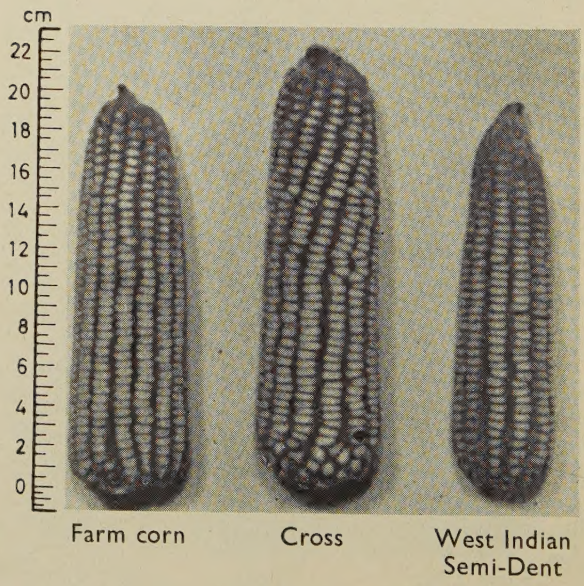

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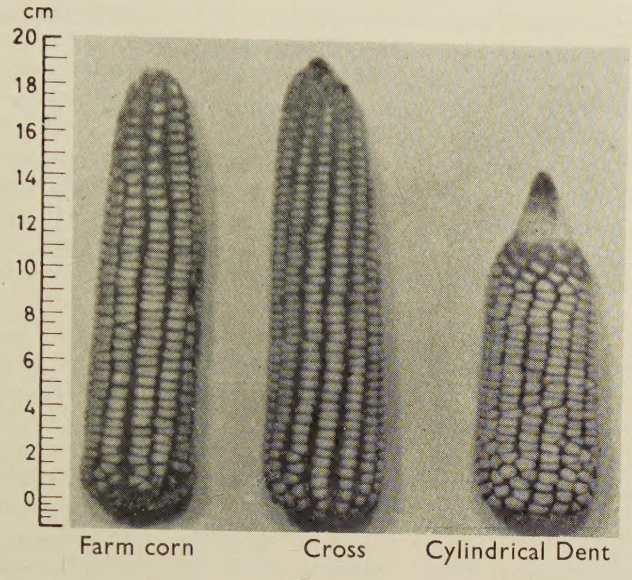

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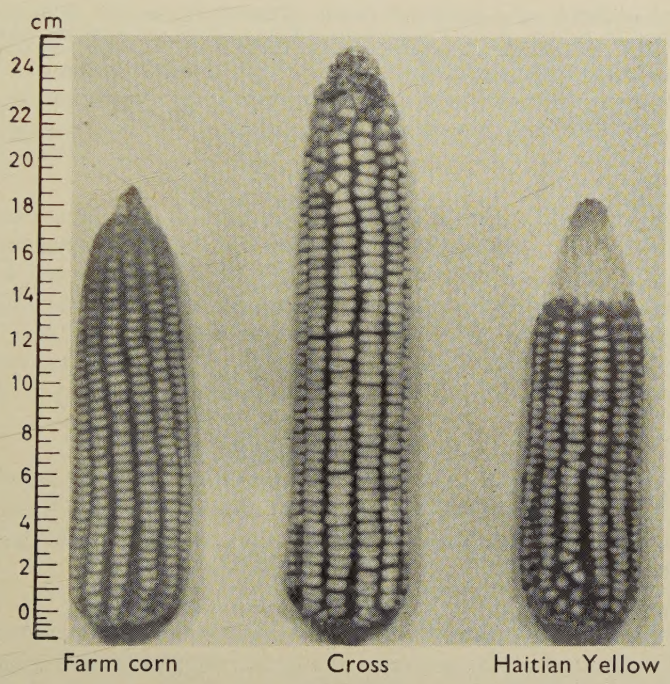

Figure 6

Figures 1 to *6* each show three typical ears from adjacent rows of this trial, that is ' Farm Corn ', top cross and the race from which the top cross was derived. The variability of ' Farm Corn ' is fairly well illustrated in these photographs and the increase in vigour of the top crosses compared to the parent races is particularly noticeable.

Trial B was conducted at the same time, comparing seven races and ' Farm Corn ' in four randomized blocks. *Table 2* shows that ' Farm Corn ' again gave the highest yield (excluding top crosses), significantly higher than four of the races. In both this trial and trial A Haitian Yellow and Maïs Chandelle were amongst the lowest yielding.

Table 2. Trial B. Mean yield of sun-dried grain in pounds per acre
Sown 12/11/56 Harvested 8/3/57

Materials	*Yield*	
	±313·1	
' Farm Corn '	3 645	*S.E. per plot* ±626·2 (21 *d.f.*)
Cylindrical Dent	3 206	*Per cent S.E. per plot* 24·6
West Indian Semi Dent	2 813	*L.S.D. 5 per cent*=920·8
Early Caribbean	2 738	*Plot size* 40 square yards net
Cuban Flint	2 707	*Spacing* Rows 1 yard apart
St Croix Long Ear	2 133	Hills 1 foot apart
Maïs Chandelle	1 981	
Haitian Yellow	1 104	
Mean	2 541	

Table 3. Mean yields in pounds per acre of dry grain (Trial C) or grain with 12 per cent moisture (Trial D) for eight races and six top crosses (T.C.) compared with a standard variety

Trial C (Trinidad)		*Trial D (Barbados)*	
Material	*Yield*	*Material*	*Yield*
S.E.	±219·3	*S.E.*	±86·1
West Indian Semi Dent T.C.	3 107	*St Croix Long Ear*	1 901
St Croix Long Ear	2 998	*Maïs Chandelle*	1 726
Cuban Flint T.C.	2 991	*Cuban Flint*	1 687
Cylindrical Dent	2 882	*Cuban Flint T.C.*	1 587
Cuban Flint	2 788	*West Indian Semi Dent*	1 545
St Croix Long Ear T.C.	2 766	*St Croix Long Ear T.C.*	1 530
Maïs Chandelle	2 701	*Haitian Yellow T.C.*	1 505
' Farm Corn '	2 672	*Haitian Yellow*	1 469
Cylindrical Dent T.C.	2 614	*Cylindrical Dent T.C.*	1 436
West Indian Semi Dent	2 570	*Coastal Tropical Flint*	1 392
Coastal Tropical Flint	2 526	*Cylindrical Dent*	1 341
Maïs Chandelle T.C.	2 367	*Maïs Chandelle T.C.*	1 310
Haitian Yellow T.C.	2 193	*West Indian Semi Dent T.C.*	1 302
Haitian Yellow	1 946	**Barbados Selected**	1 275
Early Caribbean	1 270	*Early Caribbean*	805
Mean	2 563	*Mean*	1 454
L.S.D. 5% (70 d.f.)	618·4	*L.S.D. 5% (70 d.f.)*	243
Plot size 2× 10 plants		*Plot size 3× 13 plants*	

Trial C consisted of six randomized blocks comparing the races and top crosses of trial A, as well as Early Caribbean and Coastal Tropical Flint, with ' Farm Corn '. Trial D used the same layout and races in Barbados,

except that a standard variety termed ' Barbados Selected ' was substituted for 'Farm Corn'. The results of both trials are summarized in *Table 3*. The yields in Barbados were generally lower, probably to be expected due to the lower rainfall, but the relative yields, with the exception of West Indian Semi Dent top cross, were remarkably similar considering the very different environmental conditions. The great contrast is in the position of ' Barbados Selected ' compared to ' Farm Corn '. Surprisingly, neither in Barbados nor in Trinidad did any top cross yield significantly higher than its race, but West Indian Semi Dent came very near to it in Trinidad. These results do not bear out the intial promise of the Cuban Flint top cross.

CONCLUSIONS

The results from these four trials confirm the opinion held by BROWN (1953) that certain segments of West Indian Maize may provide a promising source of germ plasm for breeding purposes. The ' Farm Corn ' which is largely West Indian Semi Dent is capable of high yields together with St Croix Long Ear and Cylindrical Dent. Cuban Flint would also appear to be useful although BROWN (1953) does not make any mention of it in connection with yield.

The yields of maize in the Federated West Indies are generally very low, but there is little doubt that they could be improved by simple programmes involving relatively little expenditure. It is unfortunate that American hybrids have been imported from time to time in the hope of achieving immediate improvement; usually only very low yields are produced. Present results suggest that more attention should be paid to indigenous maize races which seem rather promising. WELLHAUSEN and ROBERTS (1949) have already shown the value of using double top crosses as a means of rapid improvement, and there seems no reason to believe that the same methods would not be applicable in the Federated West Indies.

SUMMARY

The results of four maize yield trials are given. These trials involved Caribbean maize races and two mass-selected varieties. Trials in Trinidad indicated the relatively high yielding capacity of I.C.T.A. ' Farm Corn ' and the increase in yield obtained with top crosses of certain races with ' Farm Corn '. A trial in Barbados showed that all races, except Early Caribbean, and all top crosses yielded in excess of ' Barbados Selected '. The use of the races in improved programmes in the Caribbean is discussed.

ACKNOWLEDGEMENTS

Permission from the Director of Agriculture, Barbados, to publish the results of the yield trial grown there, and the assistance of G. E. HODNETT, Statistician, Regional Research Centre are gratefully acknowledged.

(*Received January 1960*)

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Spacing Experiments with Dwarf Beans (Phaseolus vulgaris *L.*) *in Trinidad*

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Although dwarf beans grow well in the tropics and are a most useful source of vegetable protein, little information is available on their cultivation and there is practically no published experimental work. In the U.S.A., however, experimental work on the spacing of the plants for machine cultivation has been carried out (Miller and Kimbrough, 1933; Hardenburg, 1942; Odland, 1950). In order to investigate this fundamental cultural aspect for dwarf beans cultivated by hand and grown for the sake of their edible pods, a series of spacing trials was commenced in 1954 at the Imperial College of Tropical Agriculture. In most of the experiments, fertilizers were also included as subsidiary factors. The individual trials were conducted in successive years by post-graduate students, in part fulfilment for the D.T.A. (Trin.), under the supervision of the first author.

This paper summarizes the effect of plant population on yield in this series of experiments and discusses the effect of various planting arrangements. Attention is also drawn to the economic implications of the results.

THE EXPERIMENTS

The local practice of growing beans is by hand planting on hand prepared ridges. The first trial was therefore laid down to compare a range of spacings including those normally used locally, planting both single and double rows per ridge and testing various inter-row and inter-plant distances. The investigation was continued in subsequent years by trying out a number of spacing arrangements on flattened ridges or beds of varying size (*Figure 1*).

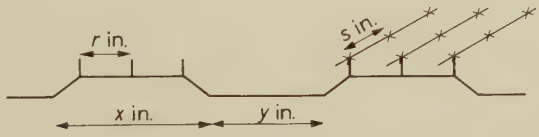

Figure 1. Arrangements of plants on beds

The inter-plant and inter-row spacings and bed widths used in the experiments, together with the corresponding mean yields, are given in *Table 1*. After the exploratory experiment in 1954, the planting pattern was standardized with 18 in. drains between the beds to facilitate preparation of ridges, planting and harvesting, while various bed widths were tried with two or three rows per bed.

The crops were grown on the College Farm during the dry season (January –March) on a light sandy-silty soil of poor inherent fertility. The variety

Table 1. Details and results of the experiments (1954–58)

Year	Design and layout: Design*	Replications	No. of plots per block	Plot dimensions ft	% S.E.	Spacing arrangements†: No. rows per bed	Bed width x in.	Inter-row spacing r in.	Drain width y in.	Mean yields of green pods lb/acre × 10^3, Inter-plant spacing s in.: 18	12	6	4	3
1954	3×3×2	4	18	7×23½‡	35·0	1	—	18, 24, 30	—	2·44	4·03	5·61		
						2	24	12	6, 12, 18	3·31	3·97	7·31		
1955	3×3×2	2	18	10×25	25·7	2	12	6	18		4·61	7·48		8·81
						2	6	3	18		4·42	7·48		8·59
1956	2×2×2	3	8	22×21¾‡	30·0	3	24	8	18		2·09	3·33		
						3	12	4	18		2·51	2·56		
1957	4×2‡	2	8	7×21	14·8	2	24	12	18		5·12	8·59		
						3	24	8	18		7·26	10·50		
1958	*single factor*	6	5	14×21	21·3	2	24	12	18		2·35	5·19		7·60
						3	24	8	18			6·07	8·63	

* Arranged in randomized blocks † See *Figure 1* ‡ Average

Contender—an American selection which had been found to be suitable in previous variety trials—was used in all the experiments. Overhead irrigation water was provided as required at the rate of 1 in. per week. The pods were harvested as they reached marketable stage (4 in. to 6 in. long and $\frac{1}{4}$ in. to $\frac{1}{2}$ in. broad), starting about six weeks after sowing; harvesting was completed in 4 to 8 pickings at about 4-day intervals. Yields were good, except in the 1956 season when the crop suffered from wet weather and a high incidence of fungus disease. Fungicides were applied in 1957 and 1958.

In all the experiments, modern randomized layouts were used and in most cases factorial designs were employed. Plot sizes ranged from 1/90 acre to 1/300 acre; the actual dimensions are given in *Table 1*. The plots within each experiment were approximately equal in area, rather than in numbers of plants. Percentage standard errors per plot were in the range 15 to 35 per cent, being smallest in the last two years when smaller blocks and improved experimental techniques were used.

RESULTS

In many spacing experiments on various crops attention has been focused on the effect of varying the inter-row or inter-plant distances, rather than on the overall effect of changes in the plant population. Preliminary examination of the results of the first experiment showed that there was a marked relationship between yield and plant population per acre, and that the various ways in which the population could be arranged were of secondary importance.

Yield response curves and estimated optimal populations per acre

The yield response curves in the individual experiments, together with the mean response curve, are shown in *Figure 2*. These curves were estimated by fitting linear equations to the logarithm of the yield per plant and the population per acre. The mean curve was obtained by taking the average slope of these lines. This form of relationship has been used by DUNCAN (1958) for corn and was found to provide a satisfactory fit to these data. It implies that the yield response curve rises to a maximum and then falls away at higher plant populations per acre. For the mean response curve, the maximum yield occurs at a population of 127 000 plants per acre. Although, unfortunately, higher populations were tested only in 1955, it is clear that usually the maxima of the individual curves will occur at populations above 100 000 plants per acre.

From the practical point of view, however, the concern of the farmer is not, in general, the attainment of the maximum possible yield but that which will give the greatest cash return at the existing prices of seed and of the harvested crop. Having estimated a mean response curve, it is possible to determine the plant population which will be 'optimum' for any given set of economic conditions. Furthermore, for advisory purposes, it is more important to know the range of plant populations over which the reduction in the maximum financial return is negligible than to know the precise optimum.

The relationship between the net monetary return and plant population is shown in *Figure 3* for different prices of seed and of the harvested crop.

Included in the quoted prices of seed is that part of the costs of planting which varies with the plant population, while W.I. $0.01 per lb was deducted from the selling price of the beans to cover the costs of harvesting. Although these calculations were based on current cultivation costs, the returns shown will not be the absolute level of net return since certain items of fixed cost such as rent, drainage and irrigation will vary.

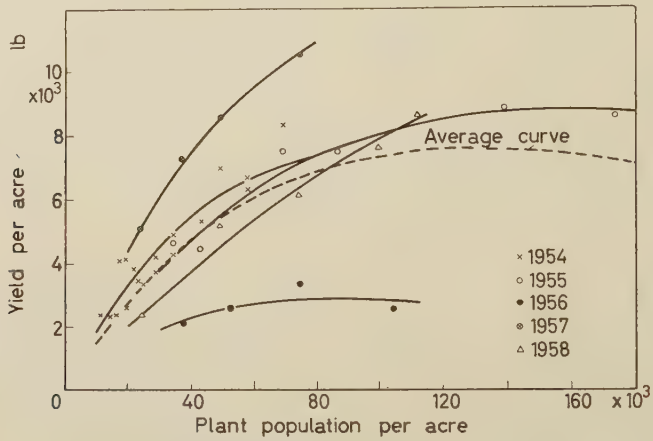

Figure 2. Effect of plant population per acre on yield

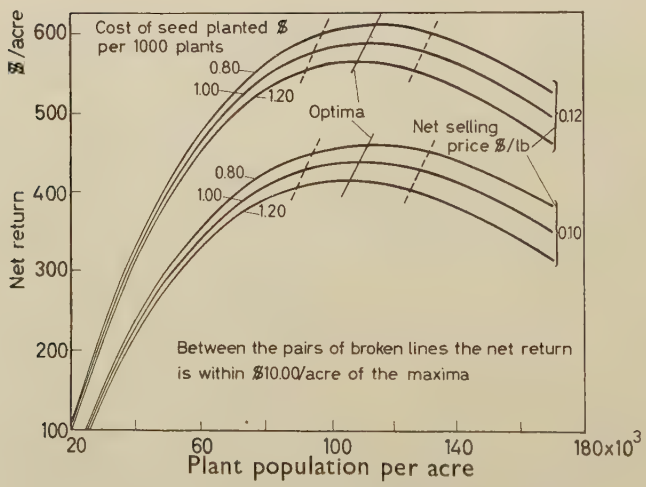

Figure 3. Net returns in relation to plant population for different prices of seed and of the harvested crop

For all the prices considered, the optimal populations are between 105 000 and 115 000 plants per acre. Moreover, within the range of plant populations indicated by the broken lines in *Figure 3*, the net returns are within W.I. $10.00 per acre of the maxima. These limits are 16 to 18 000 plants per acre on either side of the estimated optima. At W.I. $1.00 per lb

seed planted—one pound of seed gave approximately 1 000 seedlings—and a net selling price of green beans of W.I. $0.10 per lb, for example, the estimated optimum population is 109 000 plants per acre and the increase in profit by changing from say, 50 000 plants per acre to the optimum will be W.I. $150.00 per acre. At the higher selling price, the increase in profit from a similar change in plant population will be more marked, being about W.I. $200 per acre.

Populations of 40 to 50 000 plants per acre are used in local practice. Such populations are thus well below the optimum. Very substantial gains are therefore to be made by increasing populations to about 110 000 plants per acre. It is of interest to note that populations of this order are advocated for machine cultivation in the U.S.A. (HARDENBURG, 1942; ODLAND, 1950), although the actual spacing arrangements are quite different, being 2½ ft to 3 ft between rows and as close as 1 in. to 2 in. in the rows.

Effect of planting distances on yield

The effect of changes in the planting distances on the yield may be seen in *Table 1.* The yield increases as the inter-plant spacing is reduced to as close as 3 in. On the other hand, with the planting arrangements used in these experiments there was no increase in yield by reducing the distance between the rows below 6 in. to 8 in. When smaller inter-row spacings were tested, however, they were associated with narrow beds of 12 in. or 6 in. only, so that yield may have been restricted by these conditions rather than by the close spacing.

From these investigations it therefore appears that the approximate optimum population of plants of 110 000 per acre can be most conveniently achieved using the present bed system with spacing of 8 in. between triple rows and 4 in. between plants, or 12 in. between double rows and 2½ in. to 3 in. between plants. The latter is more likely to be adopted in practice.

An incidental advantage of the closer spacings was observed in the better control of weeds. With thorough pre-cultivation, weeding might be eliminated entirely. With closer spacing, however, there is more liability to disease, but this can be considerably reduced or controlled by application of suitable fungicides.

SPACING AND FERTILIZERS

There were no control plots without fertilizer in any of the experiments but in some trials different rates of application of a 2 : 4 : 1 compound fertilizer were compared. There were no significant yield differences due to fertilizer levels and no significant interaction between fertilizer and spacing, indicating that the smallest dressings of fertilizer were adequate even at the closest spacings. It is possible, however, that the fertilizers were applied too late for their full effect to be exerted during the short growth period of the crop.

SUMMARY

A series of spacing trials with dwarf beans grown for their edible pods was carried out between 1954 and 1958. The crops were grown during the dry season using hand cultivation methods. Based on an average relationship between plant population and yield, the population giving the maximum financial return (at current prices) was estimated to be about

110 000 plants per acre. This population could be conveniently achieved by planting two rows 12 in. apart on raised beds 24 in. wide and separated by drains 18 in. wide, with spacing between the plants of 2½ in. to 3 in.

ACKNOWLEDGEMENTS

Thanks are due to the following post-graduate students: A. M. COCKBURN, E. QUARTEY-PAPAFIO, G. A. IGE, T. R. BARNES, J. L. MARENAH who conducted, in successive years, the experiments summarized in this paper.

(*Received January 1960*)

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Studies on Pangola Grass at I.C.T.A., Trinidad—I. Effects of Fertilizer Application at Time of Establishment, and Cutting Interval, on the Yield of Ungrazed Pangola Grass

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Pangola grass has recently become an important pasture grass in the Caribbean area and is now extensively grown from Florida to Venezuela (Motta, 1956). Its value to grassland farming and dairy production in Trinidad and Tobago has been described by Barrie-Smith (1958), and the planting of Pangola grass is now subsidized by the Trinidad and Tobago Department of Agriculture. Some preliminary work on its grazing management has been conducted (Wilson, 1960).

In spite of its undoubted importance and widespread usage, little agronomic research has been conducted on this species grown under Trinidad conditions. The present work aims at supplying certain information on the fertilizer response of Pangola grass when grown on one of the alluvial soil types in the lowland plains of northwest Trinidad.

Certain experiments have been conducted elsewhere to assess the effects of fertilizer on the yield of Pangola grass. Thus in Florida, Wallace and Chapman (1957) compared the effects of 30, 60, 120, 240 and 480 lb of nitrogen on Pangola and found large increases in the yield per acre with the higher rates of fertilizer application, but the added increments were progressively less efficient. These workers also found that phosphate and potash applied together each at the rate of 120 lb/acre significantly increased the yield of grass over the response to an application of 60 lb of each per acre. Reus *et al.* (1957), using rates varying from 300 to 3 000 lb/acre of mixed fertilizers of different compositions and at different frequencies of application, found a curvilinear fertilizer response which demonstrated diminishing returns from each successive fertilizer increment.

Killinger (1957) stated that under average soil conditions nitrogen, phosphorus and potassium are needed in liberal quantities, that Pangola grass yields best on soil with a pH value in the range 5·5 to 6·5, and that it is responsive to changes in the level of calcium and sodium in the soil. In Hawaii, Hosaka and Goodell (1954) regarded phosphate as the most important fertilizer for high yields of Pangola. These workers applied

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as much as 200 lb of superphosphate per acre at planting time and reported excellent initial growth-response.

In Puerto Rico, RIVERA-BRENES *et al.* (1954) obtained a linear response to nitrogen in applications up to 800 lb nitrogen per acre per annum. Puerto Rican farmers apply a basic complete fertilizer (decided in relation to the particular soil) and thereafter nitrogen is applied at the rate of 400 lb of sulphate of ammonia every four months for at least two years. After this another application of mixed fertilizer is considered advisable.

In a rate-of-stocking experiment in Jamaica reported by MOTTA (1956), ten acres of fertilized Pangola were compared with ten acres of unfertilized Pangola. Over a period of three years, the fertilized pasture produced 165 lb liveweight increase per acre per annum more than the unfertilized. Fertilizer was applied annually at the rate of 3 cwt sulphate of ammonia per acre in four applications and 1 cwt potassium chloride per acre in two applications.

In Trinidad, very little work has been done on the fertilizer requirements of Pangola, despite the growing agricultural importance of this pasture grass in the island. BARRIE-SMITH (1958) recommended the application of sulphate of ammonia at the rate of 1 cwt/acre two or three times a year, but he gave no experimental justification for this. Working at I.C.T.A., EDWARD (1956) found a significant response to sulphate of ammonia for five pasture species applied at the rate of 2 cwt/acre at planting and thereafter following each cutting. This worker applied lime at the rate of 5 cwt calcium carbonate per acre, potash at the rate of 2 cwt of potassium chloride per acre, and phosphate at the rate of 3 cwt superphosphate per acre at the time of establishment. TAGOE (1956) applied 4 cwt/acre of 2N : 1P : 1K fertilizer mixture to Pangola at the time of establishment and recorded high initial yields which fell off rapidly, presumably when the nitrogen was either used up or leached out. SYKES (1956) applied fertilizer to Pangola at establishment at 6 cwt/acre of 1N : 3P : 2K followed by monthly applications of 2 cwt sulphate of ammonia alone, and found very high responses in yield due to the nitrogen top dressings.

Up to the present time the value of phosphate and potash at establishment has not been assessed and there is no experimental evidence to justify their application when planting Pangola in Trinidad. Nitrogen applications have been justified over a wide range of soils and conditions, but the optimum rate, frequency and time of application have not been experimentally assessed under any Trinidad conditions.

The present experiment was designed to add to existing knowledge on the effects of fertilizer application at the time of planting Pangola grass.

EXPERIMENTAL METHODS

(a) *Objects*

The experiment was designed to study: (*1*) The effects of different levels of nitrogen, phosphorus, potassium and calcium fertilizers applied at the time of planting on the rate of establishment of Pangola grass, and (*2*) the effects of these fertilizers, and of two different cutting intervals, on the yield of Pangola grass during the first year of growth.

(b) *Treatments*

Insufficient previous experimental work had been conducted on the College Farm to assess the requirements of Pangola grass for nitrogen, phosphates, potash and calcium. It was, therefore, decided to include fairly high rates of these fertilizers so that substantial responses might be expected under the conditions prevailing on the experimental site. The highest rates included in the treatments were 240 lb nitrogen, 180 lb phosphate, 180 lb potash and 1 400 lb ground limestone per acre. (This limestone dressing was the amount calculated to bring the reaction of the surface soil to a pH value of 7, this decision being made prior to KILLINGER's finding (1957) that a pH range of 5·5 to 6·5 was the optimum.) The treatments employed are given in *Table 1.*

Table 1. Summary of treatments

Nitrogen	N.0 Nil	N.1 80 lb/acre (4 cwt)	N.2 160 lb/acre (8 cwt)	N.3 240 lb/acre (12 cwt sulphate of ammonia)
Phosphate	P.0 Nil	P.1 180 lb/acre ($3\frac{3}{4}$ cwt triple superphosphate)		
Potash	K.0 Nil	K.1 180 lb/acre (3 cwt potassium chloride)		
Calcium	Ca.0 Nil	Ca.1 1 400 lb/acre ($12\frac{1}{2}$ cwt ground limestone)		
Cutting interval		×4: 4 weekly interval	×8: 8 weekly interval	

(c) *Design and layout*

A 4×2^3 factorial design was employed. Some of the higher order interactions were confounded to provide a layout consisting of 8 blocks of 8 units.

(d) *Plot size*

WISHART and SANDERS (1955) claimed that grass plots of 36 ft^2 gave reasonable precision where defoliation was by cutting. Allowing for a discard area round each plot, the gross plot size was 16 ft × 6 ft and the actual plot area harvested was 36 ft^2.

(e) *Site*

The experiment was sited on Field 20 of the I.C.T.A. New Farm. OLIVER (1958) has described the site in detail and given the history of the field in which the experiment was situated. Prior to the development of the field as a permanent pasture in 1949, the area had been under bamboo since 1914. The experimental results, however, showed considerable between-block variation, and the site was not as uniform as its history indicated. Unfortunately the nutrient status of the soil in question was not assessed prior to the experiment.

(f) *Planting of experiment*

It is now generally agreed that the best time for Pangola establishment is at the beginning of the ' long rains ' which normally commence in June (Barrie-Smith, 1958). However, in 1957 when the experiment was laid down, it was also common practice to plant Pangola in the ' short rains ' which occur between September and November. Preparation of land was accordingly completed by mid-October, but as the rains were late, planting was delayed until 6 November. The grass was planted in continuous drills which were 2 ft apart. Planting material consisted of unrooted stolons with green leaves attached. The whole experiment was planted in one day.

(g) *Application of fertilizers*

As no rain fell immediately after planting, application was delayed until 14 November, eight days after planting. The fertilizer was broadcast by hand, as the plots were too small to allow mechanical application.

(h) *Measurements and observations*

Qualitative estimates of establishment—All plots were scored for ' weediness ' and ' percentage grass cover ' on 19 December (six weeks after planting) and 11 February (thirteen weeks after planting).

Quantitative estimates of spreading ability and grass yield—Another worker (Oliver, 1958) measured the elongation of the stolons, the increase in the number of branches at the nodes, and the increase in the number of rooted nodes and internodal lengths. These studies are only briefly reviewed in this paper. The grass yield was measured by cutlassing the experimental plots and weighing:

(*1*) Pangola grass
(*2*) Other grasses
(*3*) Non-gramineae weeds.

The plots were harvested as follows:

12–18 March. All plots cut
22 May. All plots cut

Note. The different cutting intervals were not employed until after the completion of the first two cuts in order to allow all plots a fair chance of complete establishment and complete ground cover. After the May cut, four and eight week cutting intervals were employed.

19 June. ×4 treatments cut
10 July. All plots cut
7 August. ×4 treatments cut
4 September. All plots cut
2 October. ×4 treatments cut
1 November. All plots cut. Final harvest.

RESULTS

The overall effect of fertilizers on the yield of Pangola grass in its first year following establishment is best assessed on the total accumulative yield of Pangola grass harvested. This analysis, based on total yield of green forage, is presented in *Table 2*. *Table 2* (b) shows an overall statistically significant response to nitrogen application.

Table 2 (a). *Response to fertilizers during first year after establishment (tons fresh grass per acre)*

	N.0	N.1	N.2	N.3	*Mean*
P.0	82·2	89·3	104·8	112·9	97·3
P.1	76·8	89·5	101·8	109·3	94·4
K.0	80·7	94·0	101·6	115·1	97·9
K.1	78·3	84·8	105·0	107·1	93·8
Ca.0	83·0	91·4	104·9	114·8	98·5
Ca.1	76·0	87·4	101·7	107·4	93·1
Mean	79·5	89·4	103·3	111·1	—

S.E.=31·7; coefficient of variability=17·9 per cent

Table 2 (b). *Significance of treatment. Responses to different levels of nitrogen application during first year after establishment (tons fresh grass per acre)*

	Nitrogen treatments			
	N.3	N.2	N.1	N.0
Total yield	111·1	103·3	89·4	79·5
Increase over control	31·6*	23·8*	9·9 *n.s.*	
Increase over N.1	21·7†	13·9‡		
Increase over N.2	7·8 *n.s.*			

n.s., not significant.
† significant at $P=0·01$.
* significant at $P=0·001$.
‡ significant at $P=0·05$.

The response to the single nitrogen dressing at planting time could not be expected to continue to the November harvest, one year after application. *Table 3* indicates that there was no appreciable effect of nitrogen on yield of grass after the June–July harvests (7 to 8 months after time of application). *Table 4* presents data for the accumulative yields of grass for the early harvests, March to July inclusive. *Table 5* presents comparable data for the accumulative yields for the second half of the year, August to November inclusive. These two tables bear out the indications of *Table 3*. Up to June–July, the nitrogen response is statistically significant at $P=0·001$; after the July harvest there is no indication of a response to any fertilizer, and all F values are less than unity.

Table 3. Individual harvest response to different levels of nitrogen application (tons per acre of fresh grass)

Harvest month(s)	N.0	N.1	N.2	N.3	*Mean*
March	7·0	8·7	12·6	12·1	10·1
May	17·1	21·4	30·8	38·4	26·9
June–July	23·7	25·3	28·5	29·7	26·8
August–September	16·5	18·2	15·8	16·8	16·8
October–November	15·2	15·8	15·6	14·1	15·2
Totals	79·5	89·4	103·3	111·1	95·8

Table 4. Accumulative effect of fertilizer. Application at establishment on yield of fresh grass for the first four harvests, March–July inclusive (tons per acre)

Fertilizer	N.0	N.1	N.2	N.3	*Mean*
P.0	50·1	54·5	74·1	82·6	65·3
P.1	45·5	56·2	69·9	77·8	62·3
K.0	49·1	59·2	71·6	82·5	65·6
K.1	46·5	51·5	72·4	77·9	62·0
Ca.0	49·4	57·0	72·6	84·8	65·9
Ca.1	46·2	53·7	71·4	75·6	61·7
Mean	47·8	55·35	72·0	80·2	63·8

S.E.=23·9; coefficient of variability=20·2 per cent

Table 5. Accumulative effect of fertilizer application at establishment on yields of fresh grass for last four harvestings, August to November inclusive (tons per acre)

Fertilizer	N.0	N.1	N.2	N.3	*Mean*
	(*Difference between Tables 2 and 4*)				
P.0	32·1	34·8	30·7	30·3	32·0
P.1	31·3	33·3	31·9	31·5	32·0
K.0	31·6	34·8	30·0	32·6	32·3
K.1	31·8	33·3	32·6	29·2	31·7
Ca.0	33·6	34·4	32·3	30·0	32·6
Ca.1	29·8	33·7	30·3	31·8	31·4
Mean	31·7	34·1	31·3	30·9	32·0

S.E.=11·9; coefficient of variability=20 per cent
(No treatment differences statistically significant.)

Table 6. Effect of cutting interval (×) on yields of fresh Pangola grass for period June to November inclusive (tons per acre)

	N.0	N.1	N.2	N.3	*Mean*
×4	49·3	47·8	53·7	53·6	51·1
×8	61·5	70·8	66·1	67·6	66·5
Mean	55·4	59·3	59·9	60·6	58·8

Yield of unfertilized Pangola grass

The total accumulative yield from the control plots (N.0, P.0, K.0, Ca.0) is equivalent to 77·8 tons of green grass per acre for the twelve months period following establishment. This represents the potential yield of unfertilized Pangola grass cut under the conditions obtaining on Field 20, New Farm, during the season 1957–58. This amount is calculated from small plots, and may well be an overestimate of yield on a field scale.

Taking this into consideration, it would appear reasonable to expect initial yields of some 50 to 60 tons of green forage per acre from Pangola

pastures on soils and climates similar to those found on the College Farm. This estimate compares very favourably with 50 tons of green forage per acre obtained from highly fertilized Pangola fields in Hawaii (HOSAKA and GOODELL, 1954). Assuming a dry matter percentage of 20 (BUTTERWORTH and WILSON, 1957), the annual yield of dry matter per acre will be approximately 10 tons, twice MOTTA's (1956) estimate for Pangola grass dry matter yields in Jamaica. It seems reasonable to assume, therefore, that Pangola grass can yield at least as well, and possibly better, in Trinidad than it does in Hawaii and Jamaica.

SCHOFIELD (1945) observed that many grasses exhibit a phase of very high productivity immediately following establishment. The reason for this phase of high growth intensity was not determined. This probably accounts for the high yields in the control plots of this experiment. Yield in subsequent years might be expected to be substantially lower if Schofield's observations apply to Pangola grass in Trinidad. On the other hand, the Pangola sward in this experiment was planted at a time which is not now regarded as the best season for successful pasture establishment. It might be presumed that this fact would reduce the yield from the expected amount of Pangola grass planted at the start of the long rains in June.

Effect of fertilizers

(1) *General considerations*—The complete fertilizer dressing at the highest level employed for all nutrients (N.3; P.1; K.1; Ca.1) has a produced yield of 109 tons per acre per annum of fresh forage. However, the highest yielding treatment (N.3, P.0, K.0, Ca.1) produced an estimated 132 tons of green grass per acre per annum, an increase of nearly 70 per cent above the control (N.0; P.0; K.0; Ca.0). Although the best combinations and economic levels of fertilizer application for Pangola grass, under the conditions prevailing in Field 20, have still to be ascertained, it is quite apparent that a judicious application of fertilizers at planting time can lead to very appreciable increases in the initial yield of Pangola grass on the College Farm.

A comparison between the yield of the controls and the highest fertilizer levels (*Table 7*) reveals the effect of the fertilizers in the early stages of Pangola establishment. The highly fertilized plots gave an increase in yield of 32 per cent within 19 weeks of planting (18 weeks after fertilizer application). The increase in yield due to fertilizers reached a peak in May when they showed an increase of 112 per cent over controls. After May, the yield declined relatively faster on the fertilized plots than on the controls, and by the October–November harvest the controls yielded 6 per cent more than the highly fertilized plots. The seasonal rainfall, which probably made the fertilizers readily available in May and thereafter leached out the unabsorbed residues, is partly responsible for the changes in fertilizer response. Rainfall data for the period have been incorporated in *Table 7*.

The botanical observations on the fertilizer response on the developing plant were somewhat inconclusive and have been reported elsewhere (OLIVER, 1958), but not published. Only a brief summary of the main findings will be given here.

Table 7. Seasonal variation in yield of Pangola grass (tons of fresh grass per acre)

Month of harvest	*Rainfall 1958 in.*	*Yield of controls (a)*	*Yield of highly fertilized plots (N.3; P.1; K1; Ca.1) (b)*	*% diff. (b) over (a)*
March	0·37 (*actual*)	7·9	10·4	+ 32
May	15·29 (*actual*)	16·0	33·9	+112
June+July	11·03 (*monthly*)	19·7	29·1	+ 48
August+September	3·92 (*average*)	18·3	20·7	+ 13
October+November	6·18 (*average*)	15·8	14·9	— 6

None of the fertilizer treatments had any significant effect on internodal length. All applications of nitrogenous fertilizer appeared to depress the number of new nodes produced, but high applications of nitrogen significantly increased the number of branches at each node. The application of phosphates interacted with the nitrogen response in depressing the number of new nodes formed, although this effect could not be demonstrated with statistical significance. However, the nitrogen treatments appeared to increase the number of nodes which actually rooted and this effect was greater in the absence of potassic fertilizers than in their presence. This work indicates that the effect of nitrogen is to produce more plant material by stimulating greater branching and rooting of the nodes in the early stages rather than by increasing either the number of nodes or the distance between them. Further studies of a botanical nature on the effect of fertilizers on the mode of growth of Pangola grass are obviously needed.

(2) *Nitrogen response—Table 3* presents data for the actual yields of grass for the five harvests and for the four different levels of nitrogen application. An analysis of variance of the data showed that no fertilizer exhibited any significant interaction with nitrogen. *Table 3* shows that the response to nitrogen was clearly demonstrated at the first (March) harvest. Yields in May were directly proportional to treatment differences in March, as all yields were increased threefold in May compared to March. It is important to note that, after June–July, grass yields dropped to approximately the same level at each harvest irrespective of the rate of initial nitrogen application. Indeed, by August–September the N.2 treatment yielded less than the control, N.0.

The reason why the total accumulative yields of grass for all five harvests show a significant nitrogen response is that the early response [*Table 2* (b)] is of such a magnitude that it is still demonstrated in the final totals. *Table 3* demonstrates that, by August–September, there were no appreciable differences in yield between the different nitrogen treatments.

In terms of increased quantity of grass over controls per unit of nitrogen applied, the N.2 treatment gave the best result. This superiority of the 8 cwt dressing shows throughout the early months apart from the May harvest, when the extra returns of grass per cwt of fertilizer applied were the same for the N.2 and N.3 treatments. Costings worked out on the basis of placing an arbitrary value of W.I. $5.0 per ton on fresh grass are illustrated by the histograms in *Figure 1*. ($5 per ton was selected as this

is the price at which fresh Pangola grass is sold to peasant farmers in Trinidad.)

It is stressed that the costings worked out in *Figure 1* apply only where Pangola grass is valued at five dollars per ton. The data are limited, as application rates higher than 12 cwt of sulphate of ammonia per acre were not employed.

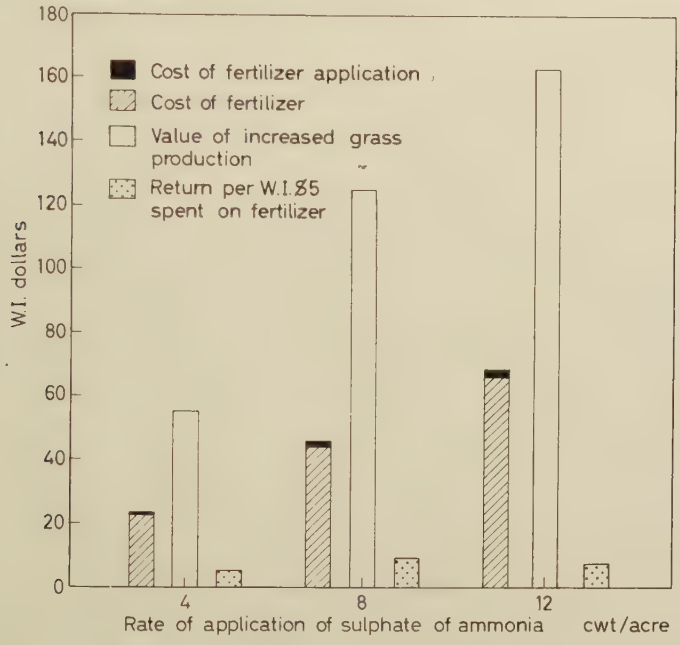

Figure 1. Histograms showing economics of response to nitrogenous fertilizer application at time of establishment of Pangola grass

(3) *Effect of lime, phosphate and potash*—None of these treatments produced any statistically significant difference in total yield of Pangola grass. The data for grass with and without calcium, phosphorus and potassium are shown in *Tables 2* (a), *4* and *5*. All three fertilizers tended to depress the yields of Pangola grass compared with the controls. In some months the depression was of the order of 10 per cent, but this difference was still below that required for statistical significance.

The absence of any response to the application of lime is of some interest, and would appear to bear out the claims made by KILLINGER (1957) that Pangola grass yields best on slightly acidic soils, in the pH range 5·5 to 6·5. The application of sufficient quantities of lime calculated to produce a neutral soil would not appear to be of any practical benefit to the successful establishment of Pangola grass pastures. The mean initial pH of soil on the site of the experiment was 5·6, within the optimum range suggested by Killinger. None of the interactions between the four fertilizers was statistically significant. No previous applications of lime, phosphate or potash are reported in the Farm records.

(4) *Effect of different cutting intervals*—Assessment of grass yield by cutting techniques introduces the question of the frequency of cutting. Some work has been done on this point, both at I.C.T.A. and elsewhere. SCHOFIELD (1945), studying the effects of season and cutting frequency on several grasses, found that, using hand shears cutting two inches above ground level, three monthly cuttings gave higher yields of fresh grass than two monthly and monthly cuts. In Jamaica, Farmer has shown that with 30 inches of rainfall per annum, Pangola can give six grazings (approximately monthly), and that at a rainfall of 100 inches per annum ten or eleven grazings can be obtained (approximately two monthly) in the rains and approximately every six weeks in the dry season. In Trinidad, TAGOE (1956) compared four, six and eight week cutting intervals on six pasture grasses, including Pangola. He found no significant difference between the eight and six week intervals, but both of them yielded significantly higher than four week intervals. SYKES (1956) compared four and eight week cutting intervals on three pasture grasses, including Pangola. He found no significant differences between the frequencies of cutting, as presumably the high and frequent application of sulphate of ammonia employed in his experiment favoured the four weekly cutting interval. In view of Tagoe's findings, and the general pattern of relationship between frequency of cuttings and yield of grass found in previous work, Sykes's results required confirmation. Four and eight week cutting intervals were accordingly used in this experiment.

An analysis of the yield data for the period June–November inclusive has been performed in order to assess the effects of the cutting treatments which were only operative after the May harvest. This analysis reveals a significant difference due to cutting interval at $P=0{\cdot}001$. *Table 6* shows that the eight week cutting interval produced an equivalent of 66·5 tons per acre of fresh grass, whilst the four week cutting interval produced only 51·1 tons.

The reason for the increase in grass production with the less frequent cutting interval is at present under study. Preliminary work suggests that the effect of frequent low defoliation is to produce a close sward with a dense mat of surface stolons which are not harvested by the technique employed. The longer cutting interval allows a semi-erect stand of Pangola grass to develop, branching at the aerial nodes, which is readily harvested by the use of a slashing cutlass or with hand shears.

It is, therefore, clearly established that the longer cutting interval is to be preferred to the monthly cutting interval when the main criterion is total yield of fresh cut grass. This result has some application where the grass is to be cut and conserved, as silage, hay or dried grass. The result may also be of significance where systems of zero grazing are adopted. However, the eight week cutting interval has distinct disadvantages when interpreted in terms of defoliation by the grazing animal. After eight weeks the sward is long and matted. The introduction of stock at this stage would result in considerable trampling and resultant grass wastage, which experience in other trials shows cannot readily be tidied up by the normal procedure of ' following herds ' of beef cattle or dry stock. Again, other work (FORSTER *et al.*, 1960) shows that the digestibility of the crude protein content of the grass may be expected to fall rapidly between four

and eight weeks. The superiority of the eight week over the four week cutting interval cannot, therefore, be taken to indicate any similar superiority of an eight week over a four week grazing cycle. Experiments on the optimum length of the grazing cycle at different seasons of the year are now in progress.

SUMMARY

(*1*) Pangola grass was shown to be capable of producing an estimated yield of approximately 78 tons per acre of fresh forage, without the application of any fertilizers, during its first year of growth. Application of 12 cwt per acre of ammonium sulphate increased this yield to an estimated 111 tons per acre. Applications of reasonable quantities of potassic, phosphatic and calcareous fertilizers had no appreciable effect on total grass yield, and nitrogen appears to be the only limiting major nutrient to high productivity during the first year of growth, under the conditions prevailing on the College Farm.

(*2*) Response to different amounts of nitrogenous fertilizer was roughly linear over the limited range examined (0 to 12 cwt sulphate of ammonia per acre). Higher applications of nitrogen might give even greater increases in initial yield of Pangola grass. When fresh grass was valued at W.I. $5 per ton, the 12 cwt dressing of sulphate of ammonia gave a net financial return of W.I. $88 per acre above that of the control, compared to a net return of W.I. $27 above the control for the 4 cwt dressing, and W.I. $72 for the 8 cwt dressing.

(*3*) The mode of action of the nitrogenous fertilizer on the grass plant is not fully understood. It appears that the increased yields stimulated by nitrogen applications are due to increased branching of the grass at each node, rather than to an increase in the total number of nodes produced or in the lengths of the internodes. Nitrogen application also appears to stimulate the adventitious rooting of the Pangola stolons at the nodes.

(*4*) None of the fertilizer interactions were statistically significant. There was an indication that the application of calcareous, potassic and phosphatic fertilizers all depressed the yield of Pangola grass.

(*5*) Of the two cutting intervals examined, the eight week interval produced higher total yields of fresh grass than the four week interval, (66 tons per acre compared to 51 tons). This result has some bearing on the cutting of Pangola grass for conservation as silage or hay, or on the utilization of Pangola grass by zero grazing, but has very limited application to optimal grazing intervals for rotational grazing systems.

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to Professor Webster for his encouragement throughout this work, to Mr Hodnett for statistical advice, to Mr Richardson for valuable criticism, and to the Imperial College of Tropical Agriculture for the provision of facilities.

The experiment was commenced by Oliver in 1957 and acknowledgement is made to the information provided by Oliver in his unpublished *D.T.A. thesis* (Oliver, 1958). The experiment was completed by one of us (S.A.A.) and the data have been fully analysed in an unpublished *A.I.C.T.A. thesis* (Adeniyi, 1959).

(*Received March 1960*)

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The Effect of Time of Planting on Behaviour of Rice Varieties in Northern Australia

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The Kimberley Research Station (lat. 15.7° S., long. 128.7° E., alt. 100 ft above mean sea level) is located in the northernmost part of Western Australia, about 60 miles from the coast. As can be seen from *Table 1*, the climate of the region is characterized by a well defined wet season between late October and early April, and a dry season from mid-April to mid-October. The wet season varies considerably in time of onset, duration and the amount of rain received. It is broken intermittently, by periods of little or no rain. Temperatures, while falling significantly in the middle of the dry season, remain sufficiently high to permit the cultivation of most tropical crops throughout the year. The major soil type is heavy alkaline clay, extremely difficult to handle when wet.

The Station was established in 1947 to investigate the possibilities of irrigation farming in the lower basin of the Ord River. In the early years several crops, including numerous rice varieties, were tested in both wet and dry seasons. The results of this preliminary screening indicated that in general *indica* varieties were more adapted to the wet season and *japonica* varieties to dry season conditions. It was, however, noted that the behaviour and performance of different rice varieties depended on the time of sowing and that usually the optimum sowing period appeared to be relatively restricted. As a result, in 1957, a systematic time of sowing experiment was undertaken, including the most promising varieties representing the main types of rice.

The trial was carried out in the field, under natural light and temperature conditions. Its primary objective was to provide preliminary information for practical farming purposes concerning the most favourable planting dates for the varieties chosen. It was considered, however, that the results would also indicate the general pattern of behaviour of the main rice types in relation to time of planting under the conditions of the north Australian environment, and thus provide a basis for more thorough future studies. Plantings were therefore made at regular intervals throughout the year, including the wet season when large-scale sowing by conventional methods would be impractical.

VARIETIES

The following 17 varieties were chosen for the trial:

Meli No. 2	:	*Indica* type from Tanganyika
Faya	:	*Indica* type from Kenya
K. 1–53	:	*Indica* type; local selection from Sindano variety from Tanganyika

A 36–3 (Hnan-Wa-Phin-Gauh)	:	*Indica* type from Burma
HR 22	:	*Indica* type from Hyderabad
RDR 7	:	*Indica* type from Hyderabad
Mas, Sigadis, Remadja, No. 2811, No. 3734	:	Indonesian *indica* (*tjereh*) types from Indonesia
Blue Bonnet, Rexoro, Magnolia	:	American *sub-indica* types from U.S.A.
Caloro	:	*Japonica* type from Murrumbidgee Irrigation Area, Australia
Taichu 65	:	*Sub-japonica* type from Malaya
C 17-56	:	Local selection from *indica* × *japonica* hybrid Rikuu 132 × GEB 24) received under FAO programme from Cuttack, India

Table 1. Climatic Averages at the Kimberley Research Station

Characteristic	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*
Rainfall (in.)	7·34	7·09	5·06	0·65	0·22	0·18
Max. temp. (°F)	97·6	95·6	97·5	94·8	91·5	86·7
Min. temp. (°F)	74·8	74·9	73·2	74·7	62·8	60·3
Length of day on first of month (h)	13·06	12·53	12·35	11·57	11·34	11·17

Characteristic	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Year*
Rainfall (in.)	0·07	0·03	0·08	0·78	2·68	4·98	29·16
Max. temp. (°F)	87·1	91·0	96·4	102·2	101·7	99·5	95·0
Min. temp. (°F)	57·8	59·9	66·2	72·3	76·0	76·0	69·1
Length of day on first of month (h)	11·12	11·23	11·48	12·14	12·42	13·00	—

EXPERIMENTAL PROCEDURES

The first planting was made on 3 December 1957, and plantings followed at 14-day intervals for a period of twelve months. The fourteenth planting failed to establish properly and had to be discarded.

To prevent birds from destroying plots maturing in the dry season, the trial was carried out in a bird-proof cage where water control on individual plots was impossible. Consequently all sowings had to be made initially in a nursery and seedlings transplanted on to the flooded plots. With the exception of the June and July sowings, transplanting was carried out in all instances 28 days after sowing in the nursery. In June and July when seedling emergence was delayed by cool weather, transplanting was carried out 21 days after emergence. The seedlings were transplanted in rows spaced 12 in. apart with 6 in. intra-row spacing.

Ammonium sulphate and superphosphate were applied at the rate of 1 cwt/acre each in the nursery and 2 cwt/acre each in the plots.

The size of the cage limited the size of the plots to 3 rows each 12 ft long. No replication or randomization of treatments was possible. Consequently no valid direct comparison of yields could be made. However, the data on vegetative growth, spikelet sterility, and dates of earing and maturity obtained in the trial provide a good guide for farming advice and for future studies of varietal behaviour in northern Australia.

Plant height and number of tillers at the time of earing were recorded to provide a measure of vegetative growth. The date of earing was recorded when it was estimated that more than 50 per cent of heads had emerged. With Meli No. 2 and A 36–3, four sowings showed extremely uneven heading. In these cases the date of emergence of the first panicles was recorded. The maturity date was recorded when the plot was considered to be ready for harvesting.

To assess spikelet sterility 25 panicles were taken at random from each treatment at maturity and the number of full and empty spikelets counted.

EXPERIMENTAL RESULTS

Plant height and tiller numbers

As can be seen from *Figure 1* the effect of time of planting on growth and tillering tended to be greater in *indica* varieties (including the *indica–japonica*

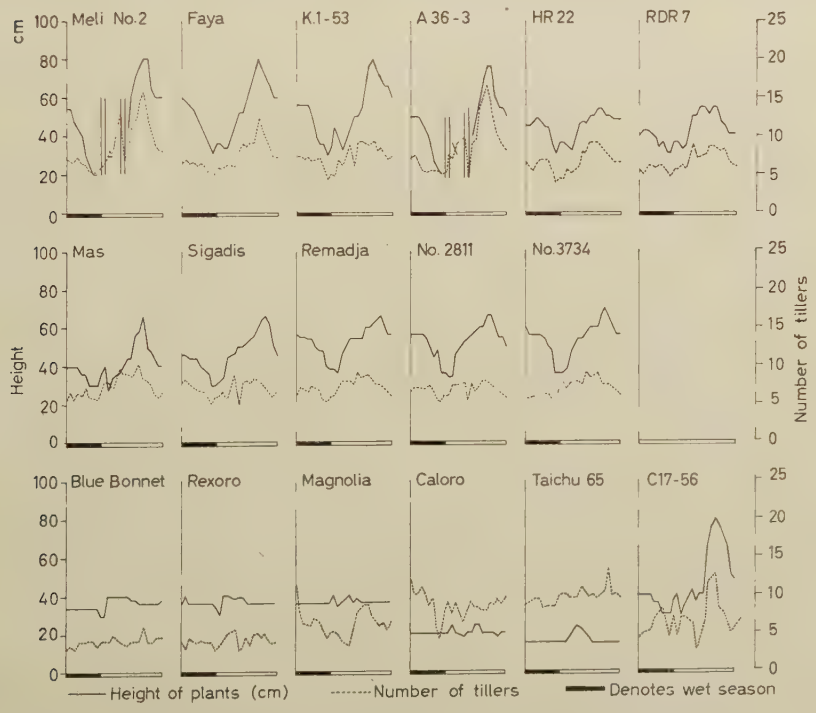

Figure 1. Height of plants and number of tillers for 17 varieties of rice planted at fortnightly intervals over the period from 3 December 1957 to 14 November 1958

hybrid C 17–56) than in others. This effect was particularly pronounced in Meli No. 2, Faya, K.1–53 and A 36–3, although the Hyderabad varieties HR 22 and RDR 7 as well as the Indonesian *tjereh* varieties showed similar trends. In general the height of the crop and the number of tillers was least with plantings made early in the dry season and most with plantings made late in the dry season. Several varieties showed a definite peak in vegetative development when planted in late August and early September. With Meli No. 2 and A 36-3 the plantings made in April and late June, as will be seen later, matured very unevenly and the height of individual plants and tillers varied considerably. The range of heights recorded in these plantings is represented in *Figure 1* by vertical lines.

The height of the American varieties Blue Bonnet, Rexoro and Magnolia, as well as that of Caloro and Taichu 65, was affected little by time of planting. There was also little effect on the tillering of Blue Bonnet, Rexoro and Taichu 65. On the other hand, tiller numbers of Magnolia differed appreciably according to date of sowing, showing two maxima associated with early December plantings and July and August plantings. Tiller numbers of Caloro showed a similar peak associated with early wet season planting.

Time to heading

The number of days between sowing and heading has been plotted in *Figure 2*. The varieties included in the trial fall into two categories. With Meli No. 2, Faya, K. 1–53 and A 36–3 the time from sowing to heading

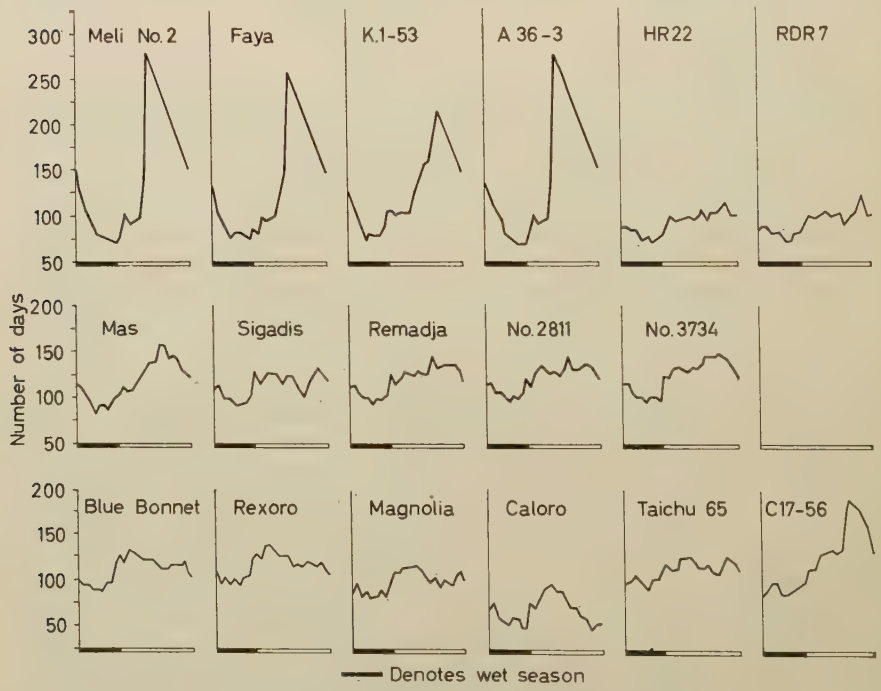

Figure 2. Number of days from sowing to earing for 17 varieties of rice planted at fortnightly intervals over the period from 3 December 1957 to 14 November 1958

varied considerably since all plantings made from late July until the end of January headed in April, in general on the same date or within a few days. In these varieties the time of heading is obviously determined mainly by photoperiodic response.

In other varieties the variation in time taken to heading was relatively smaller. The hybrid C 17–56 was an exception, showing a tendency to head in March when planted between September and December. A similar tendency could be seen in the Indonesian Mas variety. In other varieties the vegetative period tended to be shorter when planted in the wet season. The difference in behaviour of a typical photoperiod-sensitive variety (Faya) and a typical non-sensitive variety (Taichu 65) is illustrated in *Figure 3* where the periods between sowing and heading are shown for different planting dates by continuous lines.

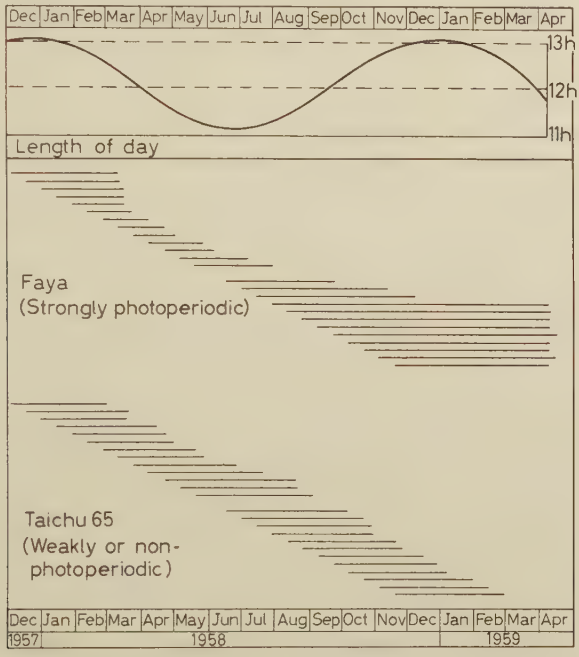

Figure 3. Dates of sowing and earing and the length of vegetative period of typical photoperiodic and non-photoperiodic varieties of rice

As has already been mentioned, Meli No. 2 and A 36–3 planted on 8 and 22 April, 17 June and 1 July showed particularly uneven heading. In these plantings the ear emergence in individual plants and even individual tillers of the same plant varied from 70 to over 200 days. In *Figure 2* this lack of uniformity is indicated by distinct points, representing the number of days to emergence of the first ears, not included in the general curve. It is interesting to note that plantings made in May did not show the same lack of uniformity in heading.

Spikelet sterility

The percentage of sterile spikelets is shown in *Figure 4*. With the exception of Faya, Taichu 65, and particularly K. 1–53, the degree of sterility

varied greatly with planting date for all varieties. In some it ranged from less than 5 per cent to over 90 per cent. The difference of a fortnight in time of planting often resulted in very appreciable differences in sterility.

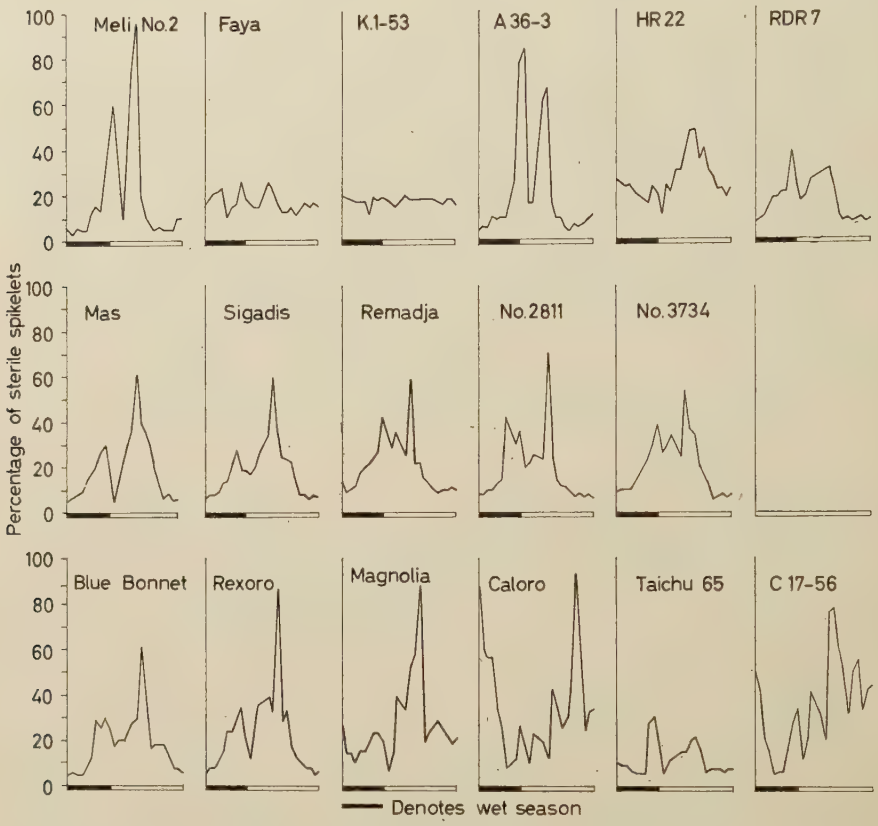

Figure 4. Percentage of sterile spikelets in 17 varieties of rice planted at fortnightly intervals over the period from 3 December 1957 to 14 November 1958

In general *indica* and American *sub-indica* varieties had more sterile spikelets when planted in the first part of the dry season, between April and July, although in several varieties sterility was noticeably lower in May plantings. Crops planted on certain dates showed a particularly high percentage of sterility. In Meli No. 2 and A 36–3 peak sterility was found in April and June plantings, which were particularly non-uniform in headings. In all Indonesian varieties peak sterility was recorded in crops planted on 1 July. In American varieties sterility peaks occurred in plantings made a fortnight or four weeks later.

On the other hand, with Caloro, spikelet sterility tended to be lowest when the crop was planted between February and June. Planting in September–October and December–January resulted in a very high degree of sterility, although sterility in the November plantings was appreciably lower. A similar tendency was recorded with the hybrid C 17–56, which showed particularly great variations in sterility percentage. The length

of the period between earing and maturity varied from 4 to 6 weeks. No appreciable intervarietal differences were recorded, although with some varieties there was a tendency towards a more prolonged maturation period during the cool part of the dry season.

DISCUSSION

The differences in the behaviour of the rice varieties described above can be attributed almost entirely to climatic variations, including day length changes, associated with different dates of planting. All treatments were planted on the same soil and by the same methods, with the exception of later transplanting of the June and July sowings which in itself was due to low temperatures.

However, no attempt has been made to establish numerical correlations between climatic variables and the data recorded. Field experiments such as this provide agronomic data in practical farming and as a starting point of more elaborate investigations. On the other hand they should not be regarded as physiological studies of plant behaviour in relation to environment. Under field conditions the environmental, particularly climatic, variables are beyond experimental control and their complexity usually prevents valid numerical interpretation of the relationship. It is therefore wiser to limit the discussion of the results to qualitative aspects.

The data plotted in *Figure 1* show that growth and tillering in the *indica* varieties tested were appreciably affected by the climatic changes associated with different planting dates. These differences can be mainly attributed to temperature conditions during the growing period. The tallest plants and greatest tillering numbers were recorded in treatments planted in the second half of the dry season when growth takes place during the hottest part of the year. On the other hand in treatments sown at the beginning of the dry season and grown during the coolest months the growth and tillering was least profuse. The greatest variations in vegetative development were found in Meli No. 2, Faya, K. 1–53 and A 36–3, and the comparison of data in *Figure 1* and *Figure 2* indicates that they are related to the differences in the length of growing period. In these varieties vegetative development is obviously the result of both temperature and length of the vegetative period.

In the American varieties, as well as in Caloro and Taichu 65, the height of plants was practically unaffected by the date of planting and, with the exception of Magnolia, the seasonal differences in tiller numbers were small. It appears that in these varieties vegetative development is determined predominantly by hereditary factors.

The data on relationships between planting dates and dates of earing permit the broad classification of the varieties sown into those strongly sensitive to photoperiod and those which are only weakly sensitive or non-sensitive. However, as has been rightly pointed out by Best (1959) in his review of photoperiodism in rice, date of planting experiments are not very suitable for research in photoperiodism. Numerous workers cited in the review have shown that other factors apart from day length affect the time of earing. Light intensity, the duration of the dawn and twilight period, atmospheric temperature and temperature of irrigation water,

atmospheric humidity, and mineral nutrition, mainly nitrogen supply, all influence the time of ear emergence, both directly and indirectly by affecting the photoperiodic response. Consequently with varieties other than those obviously strongly photoperiodic, valid interpretation of time of heading patterns is very difficult.

The tendency of Meli No. 2, Faya, K. 1–53 and A 36–3 to ear in April, and of Mas and C 17–56 to ear in March, indicates that these varieties are strongly photoperiod-sensitive. Other varieties, in which time to heading differed comparatively little between sowing dates are only weakly, if at all, sensitive.

The uneven earing in strongly photoperiod varieties, particularly Meli No. 2 and A 36–3, in treatments sown in April and June (i.e. exposed to decreasing and later increasing day lengths) can be explained by the effect of day length changes on successive tillers. However, the fact that earing was more uniform in treatments planted in May indicates that factors other than day length may also be effective in causing uneven head emergence.

From *Figure 4* it is evident that spikelet sterility patterns differ considerably among varieties. This indicates the existence of significant varietal differences in susceptibility to conditions responsible for sterility. Varieties such as Caloro and C 17–56, where fluctuations are particularly great, must be especially susceptible to more than one factor. On the other hand varieties such as Faya and K. 1–53, where sterility is little affected by date of planting, show the least susceptibility to all factors. The distinct peak in spikelet sterility associated in several *indica* and American *sub-indica* varieties with early July planting points to a single factor being especially important. In Meli No. 2 and A 36–3 high sterility is associated with extremely non-uniform earing and consequently must be caused directly or indirectly by the same climatic conditions.

Dargin (1946) quotes several reasons for sterility in rice grown in the Murrumbidgee Irrigation Area in southern Australia. A number of these, such as frost damage, faulty irrigation, excess nitrogen, and over-seeding can be discounted in this trial. Hot drying winds at the time of flowering, regarded as the most serious cause in the Murrumbidgee Irrigation Area, are also unlikely to be responsible for the high sterility which occurred in the treatments planted in early July and flowering in November when little wind was recorded. On the other hand, high sterility in these treatments could have been caused by a high maximum temperature of 42·2°C recorded in November 1958. A similar high temperature of 42·7°C occurred in February 1958 and may have been responsible for high sterility in Caloro and C 17–56 planted in December and flowering in early February. However, it is interesting to note that no corresponding increase in sterility was recorded in other varieties flowering in February.

Several Japanese workers have observed a high proportion of sterile spikelets on rice grown in cold water. For example Kondo (1954) found that when water was maintained at 20°C for a period of 60 days, sterility rose to 90 per cent. Izumi *et al.* (1957) claimed that rice is highly sensitive to water temperatures 20 to 24 days before flowering (panicle primordia stage), 12 to 14 days before flowering (reduction division stage) and during

the flowering itself. Low water temperatures in the reduction division stage caused the greatest damage. MORGAN (1953) also noted the high sterility caused by low water temperatures in California.

Water temperature records were not kept at the Kimberley Research Station during this trial. However, in 1957, when measurements were made in June and July, the mid-weekly water temperature at 7 a.m. was as low as 13·1°C in June and 17·1°C in July. Similarly low temperatures are likely to occur in August and September. Thus cold water may have been responsible for the high percentage of spikelet sterility evident in several varieties in the treatments sown in the early dry season and earing between June and September.

There is little doubt that the causes of sterility are complex and further study of the factors is necessary. However, the results obtained in this trial should be of considerable significance to commercial rice growers in the area, since almost all varieties, when sown at certain times of the year, are likely to give very poor yields due to high sterility.

PRACTICAL IMPLICATIONS

In considering the practical implications of the results of this trial, the following points have to be taken into consideration:

(*i*) between early December and mid-April conditions are generally too wet for drilling rice on a farm scale;

(*ii*) during the same period harvesting is either extremely difficult or impossible;

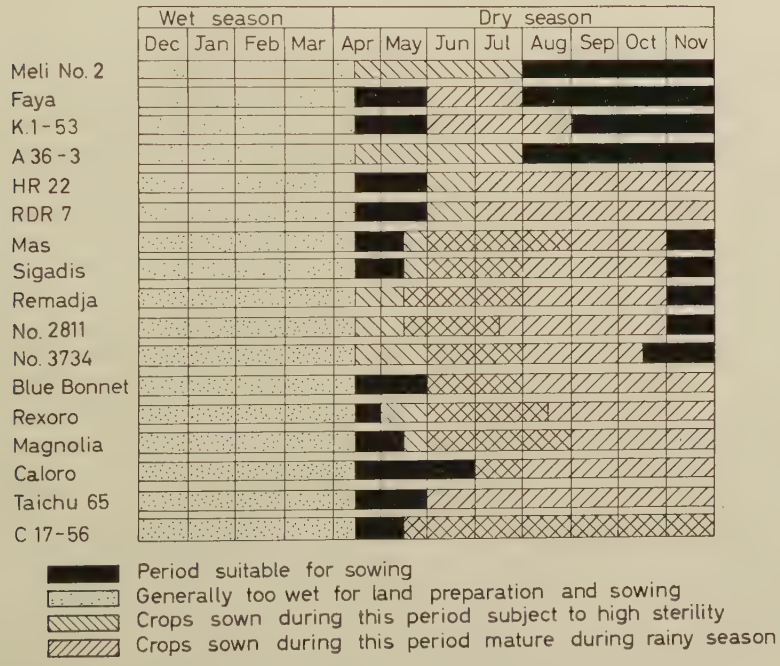

Figure 5. Tentative recommendations when to sow rice varieties in northern Australia (Practical implications of 'date-of-planting' trial)

(*iii*) high sterility, associated in some varieties with certain planting periods, leads to uneconomic yields.

The practical implications are presented in *Figure 5*. It can be seen from this diagram that the period suitable for sowing the strongly photoperiodic *indica* varieties extends from August to November. In practice, however, this sowing would be confined to late October and November to avoid an unnecessarily long vegetative period and to save irrigation water.

As far as time of maturation and sterility are concerned, *japonica* rice such as Caloro could be planted from mid-May until the end of June. However, when planted before mid-May the length of vegetative period in such varieties is very limited and as a result the yields are reduced. Consequently these varieties should be planted in late May and June.

With several varieties, planting during the wet season would lead to satisfactory results. Since at that time it is too wet for drilling by conventional methods, aerial sowing is worth considering. Difficulties were encountered in the establishment of a crop sown into water in preliminary experiments at the station, but further research is needed.

SUMMARY

A preliminary field trial including 17 rice varieties planted at fortnightly intervals throughout a year was carried out at the Kimberley Research Station in northern Australia. The results of this trial confirmed the existence of wide intervarietal differences in the effect of time of planting on height of plants, tiller numbers, time to earing and percentage of sterile spikelets.

The vegetative development of *indica* varieties was in general more affected by time of planting than that of other varieties. A number of *indica* varieties has also shown strong photoperiodic sensitivity by a tendency to ear in April when sown between late July and the end of January. When sown at other times of the year earing tended to be uneven. In two instances the unevenness was extreme and was associated with very high sterility. A majority of the varieties planted early in the dry season, and earing during or soon after the coolest part of the year, showed very high spikelet sterility. With the *japonica* variety Caloro, a similar high proportion of sterile spikelets was found in crops planted early in the wet season and maturing towards the end of it. Possible causes of the effects of date of planting on the behaviour of rice are discussed and the practical implications are considered.

(*Received February 1960*)

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Observations of Milk Yield, and Calf Growth and Conversion Rate, on Three Types of Cattle in Ghana

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Cattle farming in Ghana is at present virtually limited to areas which are free or relatively free of tsetse flies (*Glossina* spp.) in the northern and southern savannas. A few Government Agricultural Stations, however, maintain small herds of cattle in tsetse areas, with the help of fly-proof accommodation and prophylactic drugs. On the farm of the Kumasi College of Technology, situated in a partially cleared forest area with tsetse flies present, a small herd of N'Dama cattle is maintained, however, which thrives well without either fly-proof accommodation or regular administration of drugs. This herd has day-long access to an abundance of lush grass. A herd of White Fulani cattle, kept at the farm of the University College, Ibadan, Southern Nigeria, is reported by Hill to thrive under rather similar conditions (Oyenuga, 1958).

Although census data are lacking, the total cattle population of Ghana is believed to be approximately 480 000 (Ministry of Food and Agriculture, Ghana, 1959). Over three-quarters of this total are found north of lat. 9° N, the remainder being located in the southern savanna, around lat. 6° N and in scattered lagoon areas along the coast. The ratio of cattle population to superficial land area is approximately five per square mile, but when the evergreen and deciduous forest area is subtracted from the whole, the density becomes approximately nine per square mile. Density ratios vary again within the two savanna regions, mainly according to the availability of water.

Climatologically, the northern savanna is characterized by a one-peak rainfall curve, a severe dry season, considerable seasonal variations in mean monthly temperature and relative humidity, and little cloudiness.

The southern savanna exhibits a two-peak rainfall curve (maxima in May–June and in October), on the average a shorter and less severe dry season, slight seasonal variations in mean monthly temperature and relative humidity, and a higher degree of cloudiness.

In both regions the annual rainfall is considerable, viz. 30 to 50 in., but lack of adequate water conservation, except in local areas, leads occasionally to severe shortages for both man and animal. Shortage of drinking points intensifies grazing around water supplies, leading to overgrazing. Certain areas, which have no dry-season water, may hardly ever be grazed.

In the north of the country both cattle and sheep compete with arable farming. In the southern savanna, consisting mainly of the Accra plains and

the Trans-Volta Togoland region, competition for water is less acute. Since the soils in these southern areas are mostly of a difficult nature and with rainfall distribution tending to be irregular, competition between animal and arable farming is unlikely to occur for some considerable time.

The cattle in Ghana belong largely to the West African Shorthorn (W.A.S.) type, a mixture of at least three main strains, viz. Dwarf *brachyceros*, N'Dama and one or more of the different types of West African Zebu. Many farmers are in favour of a large type of animal; the use of Zebu bulls is therefore popular. In practice, however, the amount of Zebu blood is mainly determined by the density of the tsetse fly population in the different regions. A predominance of taurine types, presumed to possess a degree of tolerance against trypanosomiasis, is taken to indicate the challenge present.

Along the western border of the country infiltration of N'Dama blood from adjacent French territories occurs, whereas imports of Zebu or Sanga from the north and east have been largely responsible for certain Zebu characteristics in the modern W.A.S. Along the coastal fringes, particularly in the lagoon areas, small herds of Dwarf *brachyceros* (West African Dwarf Shorthorn) are still maintained. These animals are taurine in appearance but indicate a rather anomalous conformation (Montsma, 1959).

The Division of Animal Health has imported White Fulani cattle from Nigeria and is now establishing a small herd of Adamawa cattle from the Cameroons. White Fulani bulls have been distributed by the Division to areas which are free from or contain negligible numbers of tsetse flies.

At Nungua, the Agricultural Research Station of the University College of Ghana, situated on the Accra plains, a small herd of Sokoto Gudali Zebus from northwestern Nigeria was introduced in 1957 for comparison with other types of cattle on the station, particularly in respect of milk yield.

In the northern savanna cattle are kept in small herds, which, according to the social structure in these districts, belong to one owner, one family or one village. In the southern savanna herds are mostly of a larger size and may number up to 800 head. In many cases these herds are the property of absentee owners and are cared for by Fulani herdsmen from the north. Normally the herdsman's main, and often his only, remuneration is the right to sell milk from the herd. Particularly around the larger towns, where milk sells at one shilling per pint at present, the result of this system is that calves receive inadequate milk for normal growth and development. As a consequence, calf mortality is high and growth rates are extremely low. Many year-old calves weigh less than 110 lb. This low bodyweight is mainly the result of inadequate levels of feeding, both before and after weaning. According to Anderson (1933), feeding of concentrates at a level of 1 kg S.E. per head per day to local heifers in Northern Nigeria resulted in a hundred per cent increase in growth rate and a lowering of the age at which sexual maturity was reached.

Little is known concerning the milking potential of most types of West African cattle, except that the milk yield of the average cow is low. The only data available are obtained on research stations and Government farms and are therefore not applicable to farmers' conditions. At the Shika Stock farm (Northern Nigeria) yields of up to 3 008 lb of milk in 288 days were recorded in a herd of White Fulani cattle, which had been subjected

to selection for over twenty years. Similar data for a Sokoto herd were 2 842 lb in 294 days (FAULKNER and BROWN, 1953). Gates in 1952 recorded an individual yield of 5 805 lb in a Sokoto cow. Selected specimens of the aforementioned White Fulani herd were transferred from Shika to Ibadan in recent years. According to HILL (OYENUGA, 1958), all the cows transferred to Ibadan have exceeded, and in some cases doubled, the yields of their previous best lactations at Shika. The herd average increased from 2 757 to 3 636 lb. This suggests that production data without detailed information concerning environmental conditions are of little significance.

Reliable data for taurine cattle are even scarcer. In Sierra Leone yields of up to 1 381 lb in 263 days were obtained in a small herd of N'Dama after six years of selection under ' improved management '. Foundation stock for this herd produced 390 lb of milk in 152 days (FAULKNER and BROWN, 1953). It is not clear whether the management was improved prior to or during the six years of selection. The Animal Health Station at Pong Tamale, Northern Ghana, recorded an average milk yield of 650 lb in 185 days in a herd of ten W.A.S. (FAULKNER and EPSTEIN, 1957). JOSHI *et al.* (1957) record 282 lb in four to six months as an average lactation for W.A.S. in Nigeria, but their description of W.A.S. appears to be based on Dwarf *brachyceros* cattle rather than on W.A.S.

In the records cited above, considerable variation was shown to exist between individuals, as might have been expected in herds which were practically unselected. Some of these variations are indicated in *Table 1.*

Table 1. Typical yield data from literature

Type of cattle	*Milk yield (lb) and length of lactation (days)*			
	Average		*Maximum*	
White Fulani (Shika)	3 008	288	4 942	305
White Fulani (Ibadan)	3 636	—	5 692	305
Sokoto (Shika)	2 842	294	5 805	322
N'Dama	1 381	263	2 521	274
W.A.S.	648	185	1 437	271

Milk yields from these light-weight cows require interpretation when compared with heavier temperate breeds of cattle of beef and dairy type. Comparing milk yield per unit of body weight, a N'Dama cow yielding 2 521 lb of milk in 274 days, produces approximately 450 lb of milk per 100 lb of bodyweight, a reasonable yield under the environmental circumstances.

Few data concerning growth and maturity rates in West African cattle are available. JOSHI *et al.* (1957) report live weights in N'Dama cattle of 185 to 300 lb for male calves and 180 to 305 lb for female calves at one year of age. Age at first calving and age at first service of bulls ranged from 3 to 3·5 years. Similar data for W.A.S. are: bodyweight at one year: 193 lb; age at first calving: 3 to 3·5 years (FAULKNER and EPSTEIN, 1957). Sokoto heifers calve for the first time at forty months of age while bulls are put at service at about three years of age. Bodyweight of Sokoto calves at one year old is reported as 330 lb in males and 315 lb in females (JOSHI *et al.*, 1957).

Low milk yield and late maturity are known to be influenced by genetical and environmental factors. Low levels of nutrition during the dry season and lack of selection pressure on both sexes are likely to be the principal agents which encourage such characteristics. A long dry season subjects the animals to considerable stress and only those well adapted are likely to survive during this period. It would be unlikely that cattle would combine this specialized adaptive response with early maturity and high milk yield. If a dam produces just sufficient milk to keep its calf alive during the dry season, the two individuals have a better chance of survival than in the case of a less mutual symbiosis between cow and calf. 'The limited experiments made at Ibadan tend to show that stunted growth and low productive ability are adaptations of the animal to a low feed supply' (Oyenuga, 1958).

It was considered desirable to record production data for some locally available types of cattle, with a view to obtaining an indication of the milk-producing ability of these cattle under prevailing conditions on the Accra plains of Southern Ghana. 'Let-down' in these West African types of cattle is frequently reluctant. Cows were therefore allowed to suckle their calves, which in turn were weighed before and after suckling, thus supplying data concerning their milk consumption and growth rate. Results obtained, together with other relevant data, are presented below.

MATERIAL AND METHODS

Observations were made at the Agricultural Research Station of the University College of Ghana, at Nungua, which is situated on the Accra plains. Mean annual rainfall in the area is 26 in., 60 per cent of which falls in the period April to October. In the year of observation rainfall was below average (June 1958 till May 1959: 10 in., i.e. 40 per cent of normal). Mean monthly temperature (1500 hours) ranges from 77°F in June to 87° F in March. Mean monthly relative humidity (1500 hours) ranges from 60 to 80 per cent, at 0900 hours from 67 to 82 per cent.

Vegetation on the station 'consists dominantly of short to medium grass species, varying in composition according to type of soil; *Vetiveria*, *Brachiaria*, *Andropogon*, *Schyzachyrium* and *Monocymbium* being the most common ones. Trees and thicket species in the grassland are confined to isolated inactive termitaria' (Rose Innes, 1959).

Since the dry season during the period of these observations was severe and prolonged and the livestock density on the station high, livestock were supplied with a limited quantity of supplementary feed, consisting of millet–maize ensilage, and for a few cattle, of concentrates (maximum 2·2 lb of a 40/60 groundnut-cake–maize mixture). Notwithstanding this extra feeding cows lost up to 25 per cent of their *prepartum* bodyweight during the observations. Half of this loss was due to weight of the calf, the other half being lost during the suckling period. Suckling cows in particular were in poor condition at the end of the dry season.

The experimental herd consisted of 36 cows, 18 of which served as controls. They were taken from the foundation herds at the station according to their date of calving. The animals were of different ages in terms of number of calvings. Three different types were represented, viz. six W.A.S., six

Table 2. Milk yield, growth rate of calves and conversion rate of calves in a sample of three breeds of cattle at A.R.S., Nungua

Dam No.	Total milk yield (lb)			Weight increase of calf (lb)			Birth-weight of calf (lb)	Conversion rate lb B.W.-increase/100 lb of milk			Sex of calf
	8 weeks	13 weeks	26 weeks	8 weeks	13 weeks	26 weeks		8 weeks	13 weeks	26 weeks	
W.A.S. 3	204	317	650	25·6	39·3	118·8	43·1	11·8	12·4	18·2	f
1	258	340	646	33·5	40·4	103·2	39·7	13·0	11·9	16·0	m
4	293	462	846	34·8	61·0	153·0	42·6	12·0	13·2	18·1	f
5	337	508	921	45·5	74·6	168·7	41·3	13·5	14·7	18·3	f
2	417	586	975	54·6	75·9	157·6	40·4	13·1	13·0	16·2	f
6	426	606	1 030	51·7	77·9	180·9	50·8	12·1	12·8	17·5	m
Average	324	471	846	41·1	61·5	147·0	42·8	12·6	13·0	17·4	
Controls: Average				48·8	71·7	106·1	42·6				
Range				24–64	38–100	78–131	36–51				
N'Dama 12	317	486	884	35·7	52·2	125·4	37·7	11·2	10·7	14·2	f
8	371	575	1 037	42·2	63·7	140·5	36·9	11·4	11·1	13·6	f
10	373	548	924	43·3	63·5	133·2	37·1	11·6	11·5	14·4	f
9	395	591	995	55·3	80·1	173·2	34·6	13·5	13·6	17·4	m
7	442	662	1 117	57·7	87·7	177·6	33·3	13·1	13·2	15·9	f
11	448	673	1 128	53·5	77·5	168·9	37·1	12·0	11·5	15·0	f
Average	391	588	1 015	48·0	70·8	153·2	36·2	12·1	11·9	15·1	
Controls: Average				51·7	78·4	143·6	38·8				
Range				31–69	64–104	120–155	31–44				
Sokoto 13	389	593	1 137	50·4	81·3	196·9	57·1	13·0	13·7	17·3	m
18	502	750	1 199	63·3	91·5	193·4	47·5	12·6	12·2	16·1	m
17	515	797	1 257	58·6	92·6	205·6	62·4	11·4	11·6	16·4	m
15	568	835	1 363	76·6	106·3	221·3	46·4	13·5	12·7	16·2	m
16	644	919	1 441	74·4	106·1	215·3	51·1	11·6	11·6	14·9	m
14	757	1 074	1 585	93·2	129·9	232·0	67·5	12·3	12·1	14·6	m
Average	562	828	1 330	69·3	101·2	210·7	55·5	12·4	12·3	15·9	
Controls: Average				68·6	92·8	205·6	54·8				
Range				53–109	84–122	202–213	51–60				

N'Dama and six Sokoto in each of the two groups. Within the three types, cows were bred to one sire respectively. Calves were born between August and December 1959 and were weaned at six months of age. Sex ratio was unequal (*Table 2*), but it was not practicable to wait until a more equal ratio was available. Calves were suckled three times per day at 0600, 1130 and 1730 hours. Before and after suckling their respective bodyweights were recorded with an accuracy of 0·05 kg and corrections made to counteract losses due to urination and defaecation during the suckling period. At eight weeks of age the calves started to feed on a simple concentrate mixture (equal parts of maize and groundnut-cake plus two per cent rock salt) up to a maximum of 3·3 lb at four months of age. Limited access to grazing and ensilage was available for the calves when a few weeks old, but the intake was negligible up to two months of age. Shade was provided for the calves and concentrates were fed during the late afternoon.

Calves in the control group were with their dams throughout the day. The level of feeding of the dams was similar, but the calves had access to grazing and ensilage only, receiving no concentrates.

RESULTS AND DISCUSSION

Some of the more relevant data are recorded in *Table 2*.

First, it is emphasized that these data were not designed to give an exact picture of the productivity of cattle in Ghana, the sample being too small to serve that purpose.

Secondly, the data in respect of milk yield were obtained by weighing the calves three times daily before and after suckling and therefore do not give an exact picture of what the total production might have been if the cows had been milked twice or three times daily or with natural suckling, as occurred with the control animals, where under natural conditions calves were suckled about ten times a day. The higher number of sucklings of the control calves is likely to be the main reason for their higher initial growth rate recorded in these observations.

Milk yield

Although the average milk yield is low, variation both between and within breeds is high, amounting to a difference of almost 100 per cent between lowest and highest yielders in the W.A.S. group. This variation is the more striking if consideration is given to the unfavourable environment in which these yields were produced. Differences in milk yield were not due entirely to age differences. Several heifers, for example, indicated a considerably higher yield than mature cows. Similar results are reported by FAULKNER and BROWN (1953) in the Sokoto and White Fulani herds at Shika and by FAULKNER and EPSTEIN (1957) for a White Fulani herd in Ghana. It is possible that the heifers had a better opportunity to prepare for their first lactation than the older cows, strained as the latter probably were by their preceding lactation. It should also be emphasized that in many unimproved types of cattle, age at first calving is high, normally being three to four years.

Observations made at Nungua so far indicate that under prevailing conditions firstborn calves are significantly heavier at birth than second or

later born calves, while seasonal differences also exist in respect of birthweight. Calves born in the beginning of the dry season are significantly heavier at birth than calves born in the rainy season. In a group of 88 calves (W.A.S. and N'Dama) born at Nungua, calves born in the dry season, and therefore developed *in utero* during the wetter part of year, were nine per cent heavier at birth than calves born in the rainy season (*Table 3*).

Table 3. Birthweight, effect of sex and effect of season of birth on growth intensity (number of days required to double birthweight) in a sample of 88 calves at the A.R.S., Nungua

Period	W.A.S.			
	Birthweight (lb)		Growth intensity (days)	
	Male	Female	Male	Female
Rainy season	41·5	40·0	39	39
Dry season	44·8	42·0	50	57
Year	44·2	41·1	45	48

Period	N'Dama			
	Birthweight (lb)		Growth intensity (days)	
	Male	Female	Male	Female
Rainy season	41.3	36.6	32	36
Dry season	43·5	41·7	41	49
Year	42·4	39·1	37	42

This indicates the effect of level of feeding on the foetus and offers also further evidence in support of the assumption of the preceding paragraph (effect of age versus effect of environment).

The effect of season on quantitative milk yield is unknown, but the sudden increase in growth rate of young calves at the onset of the rainy season suggests that the effect of season on milk yield may be of major importance. The higher growth rate of young calves during the rainy season points in the same direction. Further observations in this field are in progress.

Since the calves were weaned at six months of age, no recording of milk yield took place after that period. Milk yield during the 26th week of lactation ranged from 18 to 45 lb per week. Averages for the three breeds were: W.A.S. 29 lb, N'Dama 31 lb, Sokoto 37 lb. Maximum weekly yield was obtained during the second and third week of lactation. Averages were: W.A.S. 49 lb, N'Dama 55 lb, Sokoto 82 lb.

A disadvantage of the method of recording employed arises because no fat tests of the milk could be undertaken. All attempts to secure a satisfactory

sample of milk for fat testing were unsuccessful. The maximum amount of milk obtained was 1·3 lb containing 2·8 per cent fat. The other samples were smaller and indicated even lower fat percentages. Milk samples from W.A.S. cattle, obtained at other centres, contained six to eight per cent of fat.

Growth rate

Table 2 reveals a high correlation between milk yield of dam and weight-increase of calf at eight weeks. Correlation coefficients within breeds were 0·98, 0·93, 0·96 for W.A.S., N'Dama and Sokoto respectively and 0·96 for the whole group. A possible cause of these high correlations is the relatively low milk yield of the dams, resulting in sub-maximal growth rates in the calves. The relatively high conversion rate during the first eight weeks points in the same direction. By comparison, conversion rates of male Friesian calves, fed exclusively on milk, have been recorded as below 10 kg weight-increase per 100 kg of milk (Dammers, 1959).

Within breeds, the coefficient for the correlation between milk yield and conversion rate at eight weeks was negative in the Sokoto and positive in the other breeds, but not significant at a satisfactory level of probability. Conversion rate for calves of dams yielding below average was, however, significantly lower than that for calves of dams yielding above average. Although conversion rates are apt to be affected by differences in the fat content of the milk, it is also likely that fat percentage decreases with increasing yield, thus partly counteracting differences in terms of fat-corrected milk. The differences indicated suggest that conversion rates show a maximum at a certain level of intake, and a decrease with both higher and lower levels of intake. The present sample was, however, too small to detect indications of retarded growth in the poorly fed calves by means of body measurements.

Conversion rates are also affected by differences in birthweight. The correlation coefficient between birthweight and conversion rate at eight weeks was —0·50 (significant at 5 per cent). Between breeds, differences in conversion rates were small and not significant. From other observations made at Nungua it appears that W.A.S. calves grow at a slower rate than either N'Dama or Sokoto calves. The low milk yield of the W.A.S. may be assumed to be the main cause of this low growth rate.

It was not possible to detect an effect of sex on either growth rate or conversion rate within the experimental group. Routine weighings at Nungua indicate that male calves are somewhat heavier at birth and grow at a slightly higher rate, as shown in *Table 3* for W.A.S. and N'Dama calves. Similar data for Sokoto calves are not yet available. Differences between the two breeds, though significant, are small.

Growth intensity (number of days required to double birthweight), though affected by sex and by breed, is considerably influenced by season of birth (*Table 3*). Since calves were fed almost exclusively on milk during the first few weeks, differences in growth intensity are mainly attributable to the effect of season on milk yield. It may be noted by comparison that Lüsse (1954) reports growth intensity values of 40 to 50 days in Black-pied cattle in Germany. Consideration of the data in *Table 3* indicates also that

differences in growth intensity between sexes are greater in the dry season. Part of this difference may be due to chance, the number of animals involved being small. A low growth intensity is likely to be more affected by dry season conditions, since proportionately more food other than milk has to be used. The slower growing females are therefore possibly more affected by the adverse environment.

The foregoing observations and records suggest that at present it would be inadvisable to milk the native cows in Ghana for the sale of milk. As practised, cows are milked in the morning after the younger calves have been withdrawn at least twelve hours previously. In this way at least half of the milk is lost to the calf, leading to under-nourishment and consequently to sub-optimal growth. With a limited number of the Sokoto cows under observation, a small amount of milk might have been withheld from the calf without serious effect. The author, however, has reason to believe that calves, reared without suitable supplementary feeding, require a minimum of 1 000 lb (N'Dama) to 1 550 lb (Sokoto) of milk during the first six months. This amount of milk should enable them to reach a bodyweight equivalent of five times their birthweight at six months of age. The adverse effects of milking are recognized in some of the resettlement areas in the north of Ghana in so far that the sale of locally produced milk is prohibited in those areas. Since, however, in the south of Ghana production of milk is being officially encouraged, a solution is likely to be found only by increasing the individual milk yield to a point which makes a discreet level of milking possible.

CONCLUSIONS

Although the foregoing observations offer limited evidence on which to draw many definite conclusions, they are enlightening as indicating the major importance of environmental effects on production characters under existing conditions. Similar observations, but under conditions which are more conducive to high production levels, are therefore required to verify the results indicated by the present observations.

Stewart (1956) reports that selection within the breed, as practised by him, produced disappointing results. The selected bulls were kept at an experimental station in northern Ghana and from there issued to farmers. According to Stewart, these bulls failed to produce improved progeny. This result, though disappointing, is not necessarily an indication of the failure of the methods of improvement, since the effects of environmental conditions were neglected.

The present data show sufficient evidence to warrant the conclusion that improvement of environmental conditions combined with selection within the local types of cattle, which are highly heterogeneous, is likely to have a good chance of improving production. It is possible, even probable, that introduced types of cattle would demonstrate higher productive levels than the existing local types, if both were maintained under improved conditions of husbandry, particularly feeding. Until the average nutritional level is substantially improved, however, and for as long as the potential milk and beef production of the local types of cattle under improved conditions is unknown, introduction of exotic types is unlikely to be profitable.

SUMMARY

Milk yield of dams and growth and conversion rate of calves were recorded in a sample of three types of cattle in Ghana, viz. West African Shorthorn, N'Dama and Sokoto (Zebu). Calves were suckled three times per day. Milk yield, recorded by weighing the calves before and after suckling, ranged from 645 to 1 585 lb during a period of six months recording which took place during the dry season. As a result of calving and suckling the cows lost up to 25 per cent of their *prepartum* weight. Milk yield was highest in the Sokoto (Zebu). The correlation coefficient between milk yield and growth rate up to eight weeks of age was 0·96. The conversion rate during the first eight weeks of age amounted to 12·4 lb of bodyweight-increase for every 100 lb of milk. Calves from high yielding dams had a better conversion rate than calves from low yielding dams.

It is concluded that milk yields are generally too low to warrant the sale of milk without adverse effects on the growth and general well-being of the calf.

Environmental conditions had a significant effect on milk yield, birthweight and growth rate. In general this effect was more pronounced than the influence of breed, sex or age.

ACKNOWLEDGEMENTS

Thanks are due to Mr A. S. B. Wilson, Head of the Animal Production Division, Faculty of Agriculture, University College of Ghana, for his encouragement and critical advice, and also for his correction of the English text. The author also acknowledges with thanks the work of those members of the staff of the A.R.S., Nungua, who were concerned with these observations, and the meticulous recording of M. N. Daniel, Laboratory Assistant.

(*Received January 1960*)

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Agricultural Extension Work among the Cane Growers of Fiji

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The two sugar-producing islands of the Colony of Fiji lie between 16° and 18° south latitude and 177° to 180° east longitude.

The main income of the Colony is derived from the sale of raw sugar overseas. In 1960 Fiji, under the International Sugar Agreement, has an annual export quota of 184 000 tons. This sugar is produced by four mills operated by the Colonial Sugar Refining Company.

Sugar-cane originally was grown on the plantation system but in 1924 the C.S.R. Co. began to divide some of its estates into small farms which were leased to individual Indians, who had come to the Colony as indentured labourers and worked on the estates; the average size of farms is a little less than 10 acres. C.S.R. now farms on a plantation basis only 2 400 acres, or 2 per cent of a total of 127 000 acres.

C.S.R. field officers are trained on these plantations and are stationed later among the cane growers to supervise the harvesting of crops and to advise on agricultural and other problems.

During the past ten years the number of growers and the area under the field officer's supervision have increased considerably. This change increased the administrative duties of the field officer so much that he had insufficient time to spend among growers. To remedy this position the company, in 1957, decided to organize a group of extension workers to assist growers in the field and to make available information resulting from the company's agricultural research programme.

SELECTION AND TRAINING OF PERSONNEL

At first it was specified that applicants should be Indians possessing secondary school education, some farming background and a pleasing personality, all of which would be advantageous in the work among Indian growers.

Later, people without a secondary school education had to be accepted as the required number could not all be recruited from the better educated young men. Indians were specified since 87 per cent of the growers are Indians. From 76 applications, 7 were selected and commenced a 9-week course of training.

One section of the course was designed to give the students a knowledge of the basic principles of plant growth and nutrition, soils and the action of fertilizers, simple layout of trials and weed control. To do this, simple botany, chemistry and mathematics were taught.

Two subjects of considerable importance were drainage and soil conservation. Students were trained in the use of Dumpy and Abney levels, in the fundamentals of channel design and in soil sampling and soil survey work.

The second section of the course was devoted to teaching how to pass on knowledge to growers.

A salesman gave short lectures on salesmanship, a school teacher lectured on public speaking, how to write simply and take photographs. Lectures were given and discussions took place on how to organize field days and demonstrations. Mornings were devoted to theory and the afternoons to practical work.

At the end of the course the extension assistants were assigned to areas where erosion was prevalent and the general standard of farming was poor. At first the bus and horse were the only means of transport, but these methods proved time-consuming and expensive and extension assistants were later equipped with motor scooters (*Figure 1*).

Figure 1. An Indian extension assistant on his daily rounds discusses cane-growing problems with two Indian farmers in his area

To maintain a high standard of work, the company's agronomist regularly visits the assistants in the field. The assistants are also supplied with general agricultural and specific extension literature (*Fatis Review*, *Extension Service Review*, etc.) and a 2-week refresher course is held annually.

Once in the field, the extension assistant made a general inspection of his sector, acquainting himself with the agricultural problems and the various growers. After a period, he located the growers who commanded most respect from their neighbours; they were termed 'key neighbours'. He then concentrated on persuading the 'key neighbours' to adopt better farming practices. Having done this he organized field days on the 'key neighbour' farms.

Normally the extension assistants concentrated on one project at a time in order not to confuse growers. The following are the main projects and the methods of approach used.

SOIL CONSERVATION

Much of the sugar-cane in Fiji is grown on sloping land which is often cultivated up and down the slope. Soil and fertilizer loss have been

considerable and could conceivably affect the future of cane growing in some regions.

The company cooperates with the Fiji Department of Agriculture in soil conservation work and maintains liaison to avoid duplication of work.

Because many growers accepted erosion as a natural phenomenon and were ignorant of control methods it was decided to introduce the soil conservation concept in two stages: (*1*) Get growers to plant and cultivate on the contour. (*2*) Build earthworks, such as graded banks, waterways, etc.

Planting on contour

From April 1958, when extension work commenced, until the end of June 1959, 2 308 acres were planted and cultivated on the contour as a direct result of approaches to individual growers. The average field size is about 2 to 3 acres and the project has involved a considerable number of growers.

To avoid the necessity for re-marking a contour guide line for each crop, semi-permanent lines were usually planted with vetiver grass (*Vetiveria zizanioides*). But some growers preferred to plant pigeon pea (*Cajanus cajan*), elephant grass (*Pennisetum purpureum*) or other crops on the guide lines. Vetiver grass has an advantage in that it forms a bank with trapped soil and eventually a terrace. Groups have been organized to plant vetiver grass.

Earthworks

As the principle of soil conservation became more accepted by growers, the C.S.R. Co. decided to enter the second phase. It purchased a D4 tractor and equipment for the construction of graded banks and 110 chains of graded banks were constructed in the first four weeks of operation.

Simple contour cultivation is often not enough protection against erosion for steep fields and graded banks to divert run-off are frequently essential, although expensive. One of the major problems associated with this system is the location of safe waterways or bank outlets. They are few and far between in intensively cultivated areas.

TRASH CONSERVATION

To give steep fields added protection against soil erosion, growers were persuaded to conserve cane trash instead of burning it. The most successful method is moving the trash from one row into the next. In this way weed control is better and every alternate inter-row can be cultivated to break up hard pans or roadways made by harvesting vehicles.

In the early years of the industry, trash conservation was the accepted practice. In recent years, however, there has been a change over to burning the trash.

From April 1958 until June 1959, 2 690 acres of trash were conserved between the plant and ratoon crops as a result of approaches by extension workers.

GREEN MANURE

If trash is conserved in the interval between the plant and ratoon crops, the only period when fields are open to erosion by rainfall is in the fallow

period which usually occurs in the wet season; well-grown cane gives adequate protection against erosion.

By planting a green manure crop, Mauritius bean (*Stizolobium aterrimum*), velvet bean (*S. deeringianum*), or cow pea (*Vigna* sp), protection against erosion is given during most of the fallow period. In Fiji planting green manure crops was formerly a widely accepted practice, but in recent years many growers have been growing rice in cane fallows.

Extension assistants have demonstrated better green manure varieties and are encouraging growers to pay more attention to green manure crops.

FERTILIZER ADVICE

An important part of an extension service is advising growers on fertilizers.

The extension assistants have available the knowledge gained from fertilizer trials, and the services of a soil and plant analysis laboratory. The development of a soil analysis system was the result of several years of research work by the agronomy section.

When a grower makes a request for fertilizer advice, the extension assistant accompanies him to the field. They discuss past cultivation and fertilizer practices and the assistant records this information on a card. The field is examined for soil type and at least 10 sub-samples are taken for each soil type. A sample consists of a thin slice of soil from the edge of a hole extending to plough depth. A sketch of the field and sub-sample sites is made on the back of the card.

The soil and card are returned to the laboratory. The soil is analysed and the results entered on the card. From his knowledge of the field, trial results on similar soil types and the information on the card, the extension assistant fills in a form written in Nagari script which tells the grower the quantities and kind of fertilizer required for optimum growth.

The form emphasizes that full benefit will not be obtained from fertilizers unless fields are properly drained and erosion stopped. The extension assistant personally delivers the form and explains the various sections in detail. Sometimes arrangements are also made for fertilizer to be delivered.

To demonstrate the value of fertilizers, extension assistants lay out numerous single plot trials. Each is placed so that responses can be seen easily by local growers. Field days are held at the trials and pamphlets distributed showing how the correct use of fertilizers can increase growers' net incomes.

GERMINATION

Trials showed that 'germination' could be increased by 180 per cent (average of nine trials) both by fertilizing seed cane with nitrogen and potassium 6 to 8 weeks before cutting and by dipping the setts in a mercurial fungicide. (Increase in germination due to fertilizing the seed cane occurred of course only when it was grown on land deficient in these nutrients.)

The trials and demonstrations resulted in the sale of approximately 2 tons of organic mercurial powder during 1958–59.

At planting time, field officers and extension assistants carry a small supply of the fungicide for sale to growers.

IRRIGATION

Many cane farmers grow rice on cane land. By the time the rice has been harvested the weather is often too dry to plant cane. In 1958, farmers living next to watercourses were shown how they might irrigate with small portable pumps driven by 1½ h.p. two-stroke motors. The effect of sprinkler and flood irrigation was demonstrated.

This project met with only minor success but will be continued in future seasons.

GENERAL ACTIVITIES

Extension assistants communicate ideas to growers directly by personal contact and indirectly by group contact.

Talks, illustrated by projected coloured slides, are given to growers when they gather at mill centres.

Exhibitions of extension activities are held at the annual school arts and crafts shows. Regular lectures are given to school children.

FARMERS' CLUBS

Growers have also been guided by extension assistants in the formation of Farmers' Clubs. Three clubs are functioning and three more are being formed. The aims of these clubs are to disseminate knowledge on improved farming methods (with emphasis on soil conservation) and on community development.

Talks are given on subjects such as:

Health in community life
Practical soil conservation
How your tractor engine works
Agricultural education for youths
Sports and recreation in community life
The correct use of fertilizers, etc.

Each talk is given by someone well informed in each field who is generally an Indian and who can converse readily with club members.

It is intended that clubs will visit each other to study and discuss their 'home' territory, and hold regular shows of farming skills and produce.

PRINTED MATERIAL

The C.S.R. Co. has published a series of agricultural bulletins printed in the English, Hindustani and Fijian languages. These bulletins are distributed by field officers and extension assistants.

A series of handbills and posters have been printed for various occasions.

RADIO

Extension assistants have written short talks and several plays which have been included in the Hindustani language programme of the Fiji Broadcasting Commission.

The plays illustrate some of the problems extension assistants face and overcome.

SUMMARY

Sugar-cane in Fiji is cultivated by some 13 000 growers, mainly Indians, on farms averaging a little less than 10 acres each. These growers are

largely illiterate and it proved necessary to develop an extension service to demonstrate the results of research at the agricultural experiment station.

Indians of an acceptable standard of education were trained in soil erosion and control, soil survey, cultivation and extension methods. To disseminate knowledge amongst the growers, use has been made of field days, experimental plots, colour slides, radio plays, farmers' clubs and lectures to schools. All pamphlets, posters, etc., are printed in three languages—Nagari script, Fijian and English.

The extension service has already proved of considerable benefit to growers, particularly in soil erosion control and correct fertilization. It has also enabled the research programme to be more efficiently planned.

(*Received February 1960*)

Incidence of Striga hermonthica *(Del.) Benth. on Two Varieties of Irrigated Sorghum Differently Manured, Spaced and Thinned*

F. T. Last

*Gezira Research Station, Wad Medani, Sudan**

By 1940 a stage was reached in the development of the Gezira, Sudan, at which attention could be turned from cotton, the cash crop, to improving the other crops in the rotation. As a result, the late Dr F. Crowther started a series of factorial experiments to test the effects of a wide range of cultural practices on sorghum yields. These experiments were intended to be done on disease-free sorghum but soon after planting it was apparent that the site chosen for the 1941 experiment was naturally infested with *Striga hermonthica* (Del.) Benth.—a semi-parasite that can cause large losses of yield (Wilson-Jones, 1953). Seedlings of *S. hermonthica*, a member of the Scrophulariaceae, parasitize sorghum roots and produce well developed aerial shoots with green leaves and pink flowers, but only vestigial root-systems.

The only effective method in 1941 of freeing growing crops of this semi-parasite was to hand-weed it before it flowered. Fortunately this was done systematically on four occasions, and the weights of *S. hermonthica* were taken plot by plot. As a result I have been able to assess the influence of Dr Crowther's treatments, not only on sorghum but also on the incidence of *S. hermonthica*, and these form the subject of this paper.

TREATMENTS

Variety: V1. Feterita 1931. (*Sorghum vulgare* Pers. var. *caudatum*. Stapf.)—a long strawed variety
V2. Dwarf Hegari. (*S. vulgare* Pers. var. *durra* Stapf.)—a short strawed variety

Nitrogen: N0. None
N1. 200 lb/acre of sulphate of ammonia (=40 lb N)
N2. 400 lb/acre of sulphate of ammonia (=80 lb N)

Spacing: C. 25 cm between holes
M. 50 cm between holes
W. 100 cm between holes
Throughout 80 cm between ridges

Thinning: T2—2 plants/hole
T4—4 plants/hole
T8—8 plants/hole

*Work done while seconded from Rothamsted Experimental Station, Harpenden, Herts., England.

The mean populations given by close spacing (C) and thinning to 8 plants/hole (T8) were similar, viz. 94 200 plants/acre, M and T4 gave 47 000 and W and T2 only 23 500. The extremes given by combinations of the two series of treatments were *ca.* 10 000 (W × T2) and 160 000 (C × T8) plants/acre.

Arrangement: The 54 treatments were duplicated, giving 108 plots, each 1/24 acre. Each replicate was arranged in 9 sub-blocks of 6 plots by confounding higher order interactions (see 'Z' design on pp 63–4, YATES, 1937).

METHODS

Sorghum was planted on 15 July 1941 and resown, where necessary, on 27 July. Seeds were put in holes made every 25, 50 or 100 cm along ridges, each 80 cm apart, and were irrigated when rainfall was inadequate. The last irrigation was made from 4 to 7 October, i.e. 81 to 84 days after sowing. Heads of grain were harvested from a net area of 1/33 acre/plot on 29 to 30 October (106 to 107 days after sowing), and straw two weeks later. Yields of grain given in the text refer to the weights of unthreshed heads. The ratios of grain : unthreshed heads ranged about 0·76 and were unaffected by treatments.

Seedlings were thinned to the appropriate number/hole from 6 to 8 days after sowing while they were still easy to count. Tillers started to appear two days later.

Nitrogen fertilizer was placed, eleven days after sowing, in holes made along the furrows.

S. hermonthica was sampled 50, 64, 80 and 125 days after planting—the last sample being taken immediately after the straw harvest. It was pulled by hand, air dried and weighed from an area of 1/33 acre/plot. Because the yields from different plots varied greatly (the extremes in the first sample were 3·5 and 830 g) the data were transformed, for analysis, to logarithms, and for uniformity, to lb/acre. Unfortunately some of Dr Crowther's original data have been mislaid. The total weights of *S. hermonthica*, accumulated through four samplings, were available for individual plots in both blocks and their analysis was based on 108 plots. At the separate sampling occasions, however, main effects and some first order interactions had to be analysed assuming the experiment consisted of 54 plots because only the sums of the replicates were available and not individual plot yields.

INCIDENCE OF *S. hermonthica*

Seeds of *S. hermonthica* germinate readily only when stimulated by root exudates from a limited range of host and non-host plants (MCGRATH *et al.*, 1957). Seedlings send out haustoria and of those that successfully invade sorghum roots some subsequently develop green aerial stems and flower—the others remain stunted and subterranean (ANDREWS, 1945). When these aerial stems are pulled by hand the connections between their haustoria and the hosts' roots are usually broken and regeneration is impossible. The weights of *S. hermonthica* collected at each sampling represent, therefore, the further development during the previous inter-sample period

of existing but previously subterranean parasites and/or the growth of newly established parasites.

Table 1. Rate of growth of S. hermonthica *at different stages in the development of two sorghum varieties, Feterita 1931 and Dwarf Hegari*

Variety	*Age of sorghum (days after planting)* 0–50	51–64	65–80	81–125
	Aerial growth of S. hermonthica *(lb/acre.day)*			
Feterita 1931	0·12	4·9	7·0	1·2
Dwarf Hegari	0·14	3·1	3·7	0·8
Mean	0·13	4·0	5·4	1·0

Variety

S. hermonthica developed equally on both varieties for the first 50 days but subsequently more developed on Feterita than Dwarf Hegari. The difference was greatest from 65 to 80 days after planting when *S. hermonthica* developed nearly twice as rapidly on Feterita as on Dwarf Hegari. The effects of these varietal differences are reflected in the progressive cumulative weights given in *Figure 1*. By the end of the experiment, 125 days after planting, 240 and 144 lb of *S. hermonthica* developed per acre of Feterita and Dwarf Hegari respectively.

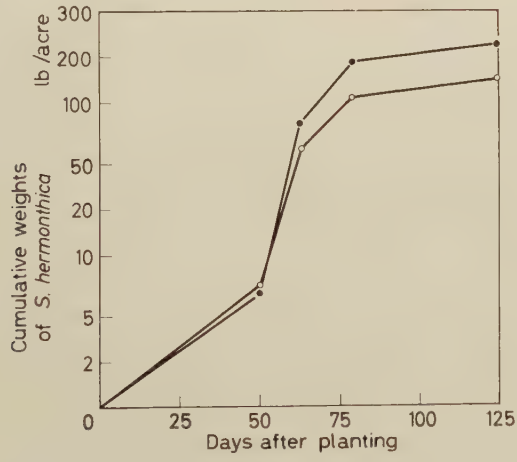

Figure 1. Seasonal incidence of S. hermonthica *on two sorghum varieties (•, Feterita 1931; °, Dwarf Hegari)*

Spacing

The effect of spacing differed with the different varieties and at different stages in their growth. For the first 50 days increasing the space between holes from 25 to 50 and 100 cm decreased the growth of *S. hermonthica* on Feterita and Dwarf Hegari equally—the mean weights decreased from 13 to 5·8 and 3·1 lb/acre respectively (*Figure 2*). Later, however, only the widest spacing significantly decreased the growth of *S. hermonthica* and only

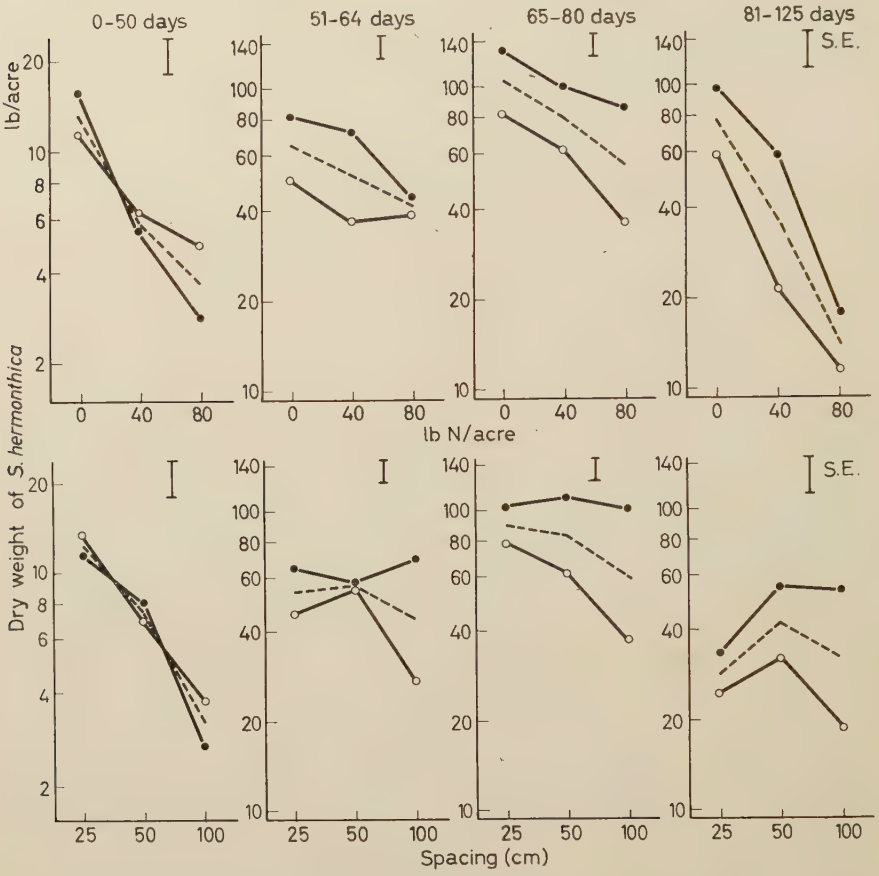

Figure 2. Effects of nitrogen and different spacing treatments applied to two sorghum varieties on the aerial growth of S. hermonthica *within each inter-sample period (•, Feterita 1931, °, Dwarf Hegari and - -, mean varietal effect. Standard errors apply to separate varieties)*

on Dwarf Hegari. This continued effect on widely spaced Dwarf Hegari significantly decreased the total weights of *S. hermonthica* produced throughout the season—the other early effects were subsequently masked (*Figure 3*).

Spacing Dwarf Hegari at 100 cm decreased *Striga* more on unmanured than on manured plots (*Table 2*). Widening the spacing of unmanured crops from 25 to 100 cm decreased the weight of *S. hermonthica* from 224 to 98 lb/acre and in crops given 80 lb N/acre from 78 to 56 lb/acre.

Nitrogen

Unlike most of the spacing treatments, the main effects of nitrogen persisted throughout the season and affected both varieties similarly. The accumulated total weights of *S. hermonthica*, sampled on four occasions, decreased from 245 lb/acre in the unmanured plots to 162 and 93 lb after adding 40 and 80 lb N/acre respectively (means of both varieties, *Figure 3*).

The size of the nitrogen effect, although similar on Feterita and Dwarf Hegari, varied greatly during their development (*Figure 2*). In the first

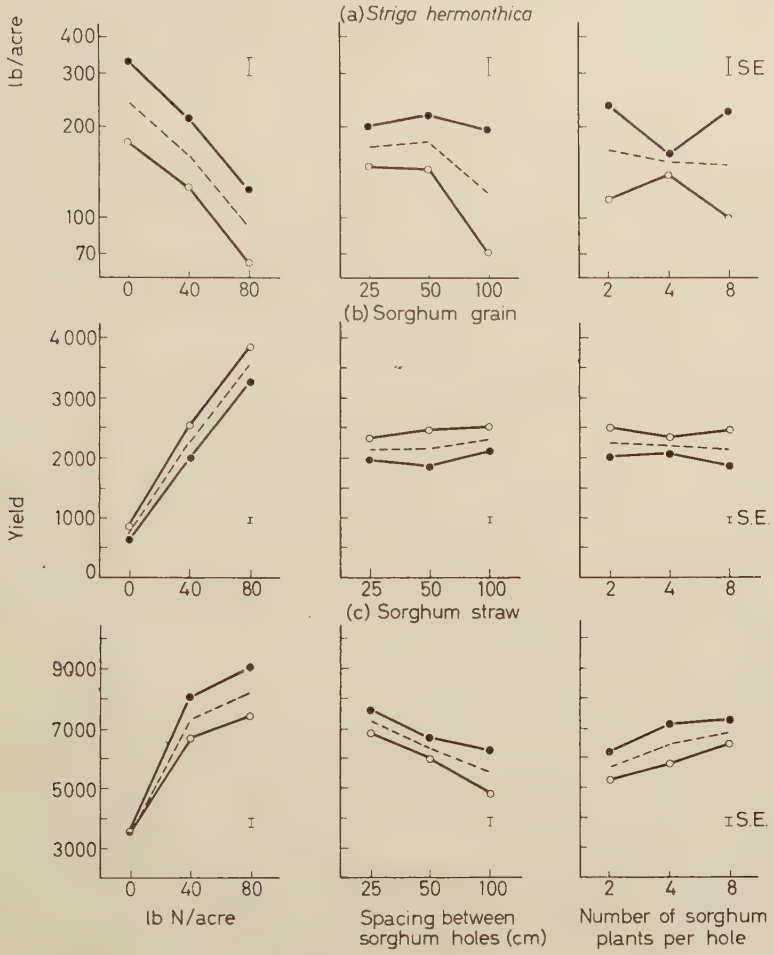

Figure 3. Effects of nitrogenous fertilizer, sorghum varieties, spacing and thinning treatments on (a) *growth of* S. hermonthica *and yields of sorghum,* (b) *grain and* (c) *straw* (●, *Feterita 1931;* °, *Dwarf Hegari; and* - - -, *mean varietal effect*)

50 days after planting, nearly four times as much *S. hermonthica* developed on unmanured crops as on crops given 80 lb N/acre. Together with wide spacing, adding 80 lb N/acre decreased the weight of *S. hermonthica* from 33·3 lb in the closely spaced unmanured crops to 1·8 lb/acre (*Table 3*).

Later, from 51 to 80 days after planting, the difference between the amounts of *S. hermonthica* growing on unmanured and manured crops decreased to a factor of less than 2 (from 51 to 64 days × 1·6; from 65 to 80 days × 1·9) only to increase again to a factor of × 5·2 from 81 to 125 days after planting.

Thinning

The weights of *S. hermonthica* per acre were not affected by the numbers of plants per hole.

Table 2. Effects of variety, sulphate of ammonia and spacing on the incidence of S. hermonthica *(logarithms of the cumulative total weights, lb/acre)*

Variety		lb N/acre 0	40·0	80·0	Mean
Feterita 1931			(±0·099)		(±0·057)
Spacing	*Close*	2·51	2·31	2·07	2·30
	Medium	2·58	2·36	2·08	2·34
	Wide	2·47	2·30	2·11	2·29
	Mean (±0·057)	2·52	2·32	2·09	
Dwarf Hegari			(±0·099)		(±0·057)
Spacing	*Close*	2·35	2·27	1·89	2·17
	Medium	2·41	2·16	1·90	2·16
	Wide	1·99	1·88	1·75	1·87
	Mean (±0·057)	2·25	2·10	1·85	

Table 3. Effects of sulphate of ammonia and different spacings on the aerial growth of S. hermonthica *during the first 50 days after planting sorghum (means of two varieties, transformed data shown black)*

Intervals between groups of sorghum	*No* N	N/*acre* 40 *lb*	80 *lb*	*Mean* (±**0·083**)
	Air dry wt of S. hermonthica, *lb/acre* (±**0·143**)			
25 cm	33·3	9·1	6·4	
	1·52	**0·96**	**0·80**	**1·10**
50 cm	12·3	7·3	4·5	
	1·09	**0·86**	**0·65**	**0·87**
100 cm	5·5	3·0	1·8	
	0·74	**0·47**	**0·25**	**0·49**
Mean (±**0·083**)	**1·12**	**0·77**	**0·57**	

SORGHUM YIELDS

Grain yields of irrigated sorghum, unlike rain-grown sorghum (DOGGETT, 1952 and COLLINGS-WELLS, 1954), seem to be little affected by a wide range of plant populations. In the U.S.A. varying the numbers of plants from 72 000 to 228 000 per acre did not affect grain yields (NELSON, 1952) and in the present experiment 10 000 and 162 000 plants per acre gave similar grain yields but yields of straw differed significantly—higher yields were given by the higher plant populations (*Figure 4*).

Grain

Comparison of the graphs in *Figure 3* stresses the outstanding importance of nitrogen in controlling the yield of grain per acre. Adding 80 lb N/acre quadrupled the grain yields of both varieties.

Spacing and thinning had only minor effects on yields per acre but greatly altered the yield per plant. Doubling the number of plants, by

decreasing the spacing between holes from 50 to 25 cm, did not affect yields per acre but halved yields per plant; increasing the spacing from 50 to 100 cm again had no significant effect on yield per acre but doubled the yield per plant. Similarly, drastic thinning from 8 to 4 and 2 plants per hole had no effect on grain yields per acre because yields per plant increased and compensated for the smaller plant populations.

Straw

Without nitrogen both varieties gave similar yields of straw but, unlike grain yields which were affected equally by nitrogen, the taller variety Feterita responded more than Dwarf Hegari to nitrogen. The straw yields

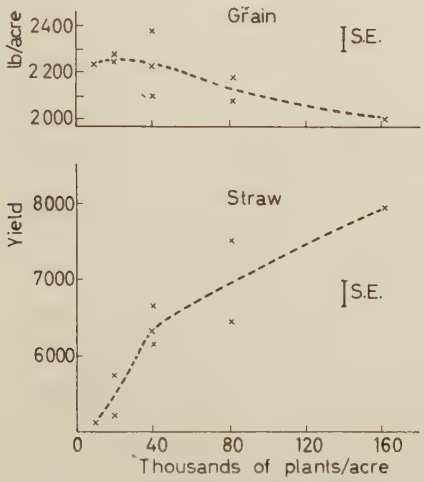

Figure 4. Yields per acre of sorghum grain and straw given by different plant populations

of Feterita increased from 3 540 to 8 990 lb/acre with 80 lb N/acre and of Dwarf Hegari from 3 570 to only 7 350 lb/acre.

In contrast to their effects on grain, the spacing and thinning treatments significantly affected straw yields per acre. When the numbers of plants were quartered, by altering either the spacing between holes or the numbers of plants per hole, the straw yields per plant were not quadrupled as with grain but instead increased by factors of only $\times 3{\cdot}0$ (spacing) and $\times 3{\cdot}3$ (thinning), with consequent significant decreases in yields per acre.

DISCUSSION

In the Gezira sorghum usually emerges about six days after sowing while green aerial shoots of the semi-parasitic *S. hermonthica* rarely appear for another 14 to 21 days. This delay is probably mainly responsible for the small amounts of foliage produced in the first 50 days of the experiment. Later, however, the aerial growth of *S. hermonthica* reached a maximum rate of 5·4 lb (dry weight)/acre.day, from 65 to 80 days after sowing, to decline later as the host aged.

The weights of *S. hermonthica* represent the development of only a small proportion of the established root parasites—the majority remain stunted and subterranean. In pot experiments the numbers of *S. hermonthica* (ANDREWS, 1945) and of *S. densiflora* and *S. lutea* (KUMAR *et al.*, 1949) parasitizing sorghum roots increased progressively during the first four to five weeks and then tended to remain constant. Although numbers probably continue to increase for longer in the field, because the host would be less restricted than in pots, the weights of *S. hermonthica* produced in the second (starting in the eighth week) third and fourth inter-sample periods probably mainly reflect the aerial growth of established parasites, which were previously stunted and subterranean, and to only a lesser extent the growth of entirely new parasites.

Sorghum left unweeded in Northern Nigeria produced 26 000 aerial stems of *S. senegalensis* per acre and when repeatedly hand-weeded produced 112 000 stems (BUTLER, 1957). These results suggest that nutrients become available for existing subterranean parasites to develop green foliage when parasites with aerial stems are removed and that the ratio of aerial:non-aerial parasites is maintained by competition for host materials. If this

Table 4. Incidence of Odontites verna *(=Red Bartsia) at Rothamsted (1933 to 1953) in plots of differently manured winter-sown wheat, assessed using an arbitrary scale (the larger the infestation, the higher the index)*

Date	*No manures*	*Minerals**	*Fertilizer treatments* *Minerals+cwt/acre S/A†* 2	4	6	*Minerals+cwt/acre N/S‡* 2½	5
			Mean grain yields 1935 to 1954 (cwt/acre)				
	12·5	14·5	17·5	20·5	22·5	18·5	22·5
			Incidence of O. verna				
May	73	47	51	7	0	16	17
August	145	125	109	22	2	35	22

*Minerals denotes 3½ cwt superphosphate, 2 cwt sulphate of potash, 1 cwt sulphate of soda and 1 cwt sulphate of magnesia/ acre.year.

†S/A denotes sulphate of ammonia. ‡N/S denotes nitrate of soda.

interpretation is correct, the data from the present experiment, excluding those for the initial lag phase of 50 days, indicate that the supply of materials extracted from the host is maintained until the sorghum grain crop is nearly ripe.

The *Striga* germination factor, which seems to be secreted by root tips only, has its greatest effect in the immediate rhizosphere and its effect declines rapidly with increasing distance from the root (PEARSON, 1912 and BROWN and EDWARDS, 1944). In the present experiment in which grain yields were quadrupled, nitrogen probably greatly increased the size and spread of the host's roots and also the numbers of *Striga* seeds influenced by root exudates. But, instead of increasing the weights of aerial *S. hermonthica*, nitrogen decreased its growth. Perhaps deficient plants secrete more exudate per unit of root than plants given nitrogen, and become more frequently parasitized. This is, however, improbable because the *Striga* stimulant, like the eelworm-hatching factor produced by potato roots (WIDDOWSON, 1958), is produced most abundantly by actively growing tissue (BROWN and EDWARDS, 1944). Instead, nitrogen probably acts indirectly by affecting the later balance between host and parasite.

The effects of nitrogenous fertilizer in decreasing the aerial growth of *S. hermonthica*, which have been confirmed in the Sudan since the experiment described in this paper was done (LAST, 1960), are similar to its effects on the development of the related *Odontites verna* (Bell.) Dum [=*Bartsia Odontites* (L.) Huds.]. On Broadbalk field, Rothamsted Experimental Station, the incidence of *O. verna*, commonly known as Red Bartsia, in winter-sown wheat (October to November) is assessed in the spring (May) and at harvest (August) using an arbitrary scale—the larger the infestation, the higher the index (*Table 4*). From 1933 to 1953 its incidence varied greatly from season to season but consistently more developed on the low yielding crops without nitrogen, than on the high yielding crops given at least 4 cwt of sulphate of ammonia, or the equivalent, per acre. This decrease like that of *S. hermonthica* may be caused by direct competition with the host, e.g. for light, but this is unlikely to be the only explanation because nitrogen decreased the incidence of *S. hermonthica* by a factor of 1/3·5 within 50 days of planting, before shading seemed to be important. Its largest effects coincided with the periods when *S. hermonthica* produced least foliage. In early and late stages of the sorghum crop when 0·13 and 1·0 lb of *S. hermonthica* were produced per acre per day, 3·5 and 5·2 times more parasite grew on unmanured crops than on crops given nitrogen. From 51 to 80 days after planting, when at least 4·0 lb *S. hermonthica* grew per acre per day, the ratio of *S. hermonthica* in unmanured:manured crops decreased to less than two.

Shading may decrease the size of individual stems, but competition for light is unlikely to account directly for the fewer stems of *S. densiflora* and *S. lutea* emerging when SOLOMON (1952) progressively increased the amounts of nitrogen, phosphorus and potassium given to sorghum. These fertilizers may decrease the number of *Striga* seedlings parasitizing roots like the effect of superphosphate on the development of *Orobanche ramosa* L. when given to *Carum ajowan* Benth. et Hook. (RACOVITZA, 1959). Alternatively, they may decrease the ratio of aerial:non-aerial parasites. ANDREWS (1947) found that although 5 per cent of the *S. hermonthica* seedlings parasitizing sorghum developed aerial stems, only 2 per cent of those on plants rich in nitrogen, viz. legumes, appeared above ground and even these rarely flowered. Similarly, in experiments done in the Sudan during 1956–7, I noticed that *S. hermonthica* remained stunted and flowered less profusely on sorghum given sulphate of ammonia than on unmanured crops (LAST, 1960).

Well grown sorghum crops may therefore resist infection and decrease the proportion of parasites developing aerial stems. They may, by withholding essential nutrients, limit the size of these aerial stems which, in turn, may be adversely affected by competition with the host, at least for light.

The development of *Striga* spp. and of *Odontites verna* contrasts sharply with the development of *Orobanche ramosa* L. Instead of decreasing, *Orobanche ramosa* develops more profusely on well grown than on poorly grown *Cannabis sativa* (CAJLACHJAN, 1947). Similarly HOLDSWORTH and NUTMAN (1947) found that flowering stems of *Orobanche minor* developed more rapidly on large red clover plants grown in long-days than on small plants grown in short-days.

The early effects of spacing seem to parallel the effects of nitrogen. In the first 50 days after planting, 13·1 lb of *S. hermonthica* developed per acre of unmanured crops and 3·7 lb on crops with 80 lb N/acre; 12·4 lb of *S. hermonthica* grew on closely spaced crops and 3·1 lb on widely spaced crops. When, however, the weights of *S. hermonthica* are expressed as lb per host instead of lb per acre, their modes of action obviously differ. The effect of nitrogen is the same whether expressed per acre or per host. In contrast the spacing effect disappears when expressed as lb per host because there were 4 and 2 times as many groups of plants in crops spaced at 25 and 50 cm intervals as in crops spaced at 100 cm. 3·1 lb of *S. hermonthica* developed on the widest spaced crops and 3·7 (=7·4 lb/2) and 3·1 (12·4 lb/4) on comparable numbers of sorghum spaced at 50 and 25 cm respectively. Later the parasite developed more profusely on widely spaced than on closely spaced sorghum and as a result the effect of spacing on the weight of *S. hermonthica* per acre decreased. In contrast, SAUNDERS (1933) found that changing the spacing affected the development of *S. lutea* throughout the season and increasing the interval between maize plants within a row from 9 to 18 and 36 in. decreased the numbers of parasitic aerial stems per host from 3·21 to 1·00 and 0·13 respectively. The discrepancy between the two experiments may possibly be attributed to an interaction between the effects of spacing and different levels of soil fertility. In the present experiment the decreases caused by increasing the space between sorghum plants were largest with unmanured crops and least with crops given 80 lb N/acre.

Early infestations of *S. hermonthica* usually decrease both grain and straw yields; late infestations decrease only straw yields (LAST, 1960). In the present experiment it is difficult to assess the damage done by *S. hermonthica* but the infestation probably vitiated the effects of some of the cultural treatments. The fourfold increases of grain and straw, obtained by adding 80 lb N/acre, may partly be attributed to the lower incidence of the parasite especially in the young crop.

SUMMARY

Foliage of the semi-parasitic *Striga hermonthica* growing on two sorghum varieties, Dwarf Hegari and Feterita 1931, was collected, air dried and weighed on four occasions. It grew at different rates at different stages of sorghum development and reached a peak *ca.* 5·4 lb/acre/day from 65 to 80 days after planting. Less developed on Dwarf Hegari than on Feterita.

Adding 80 lb N/acre, as sulphate of ammonia, increased grain and straw yields but decreased the total aerial growth of *S. hermonthica* from a mean (for the two varieties) of 245 lb in unmanured crops to 98 lb/acre. The decreases were relatively smaller from 51 to 80 days after planting sorghum, when *S. hermonthica* was developing rapidly, than in earlier and later stages of the host's growth.

Straw yields of unmanured crops of both varieties were similar, *ca.* 3 350 lb/acre, but Dwarf Hegari yielded more grain. Adding 80 lb N/acre increased straw yields of the long-strawed Feterita to 9 000 lb and of the short-strawed Dwarf Hegari to 7 350 lb/acre: it increased mean grain yields of both varieties similarly, from 760 to 3 540 lb/acre.

Widening the spaces between planting holes from 25 to 100 cm and thinning the number of plants per hole from 8 to 2 did not affect the yields of grain per acre but quadrupled the yields per plant of both varieties; the straw yields per plant increased by a factor of about $\times 3{\cdot}2$, instead of $\times 4{\cdot}0$, with consequent significant decreases per acre. Yields of grain per acre were the same over the whole range of plant populations given by combinations of the various spacing and thinning treatments, viz. 10 000 to 160 000 plants/acre, but straw yields increased progressively with increasing plant number.

In the first seven weeks after planting, spacing affected weights of *S. hermonthica* per acre but not weights per host—less *S. hermonthica* grew per acre on widely than on closely spaced crops of both varieties. Later, more *S. hermonthica* developed per host spaced at 50 and 100 than at 25 cm, so masking the earlier effects per acre; the increases on Dwarf Hegari were less than on Feterita.

From the start, four times as much *S. hermonthica* grew per host where there were two instead of eight plants/hole and as a result the weights per acre were unaffected.

ACKNOWLEDGEMENTS

I am much indebted to members of the Gezira Research Station for their help in finding Dr CROWTHER's original data, and I thank Miss J. M. THURSTON for allowing me to use her unpublished results showing the effects of fertilizers on the incidence of *Odontites verna* in winter wheat on Broadbalk, Rothamsted.

(*Received February 1960*)

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Leaf and Stem Infections of Theobroma cacao *L. in West Africa, Caused by* Phytophthora palmivora *(Butl.) Butl.*

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The first records of *Phytophthora* species attacking leaves and young stems of *Theobroma cacao* L. in West Africa were those of a seedling blight in Nigeria, described by Chant (1957), and of a disease with identical symptoms in Ghana reported by Wharton (1959). Prior to this, damage to cacao by the genus in West Africa was thought to be confined to *P. palmivora* causing pod rot and cankers of bark and flower cushions. This species was not known to cause leaf and stem die-back of mature trees as it does in other cacao-growing countries, although Wharton (1959) had found a *Phytophthora* sp. associated with a tip necrosis of flush leaves in the Southern Cameroons. Recently, the authors have identified *P. palmivora* attacking leaves and shoots of mature trees in Ghana, and similar infections have been seen in Nigeria, Southern Cameroons, Fernando Po and Cameroun. This paper describes the disease symptoms in Ghana and compares the identity of the pathogen with that of isolates of *P. palmivora* from other territories.

SYMPTOMS AND DISTRIBUTION OF THE DISEASE

In June, 1959, a leaf blight and die-back of chupons was found on cacao trees in a farm on the escarpment at Mpraeso in Southern Ghana at an elevation of over 2 000 ft. The escarpment is enveloped in low cloud for much of the year and under such climatic conditions the farm had been virtually abandoned by its owner because of the extremely high crop losses caused by black pod disease. Symptoms on flush leaves (*Figure 1*) appeared identical with those described by Wharton (1959) for tip necrosis in the Southern Cameroons; a wet rot developed rapidly down the main veins, usually starting from the leaf tip. The chocolate brown necrosis was, characteristically, preceded by a translucent band of tissue of variable width. Older diseased leaves were seen where the tissues had matured and restricted spread of the pathogen, leaving a dark brown, withered tip which sometimes fell off. Most new chupons were severely blighted; symptoms on these shoots (*Figure 2*) resembled damage caused by Mirid pests, but differed in that the lesions were sunken and were more widespread and extensive in the stem tissue. There was also apparently indirect infection of chupons from the petioles of infected, immature flush leaves that spread downwards and caused a general tip die-back. The disease

Figure 1. Flush leaf of Amelonado cocoa infected with P. palmivora

Figure 2. P. palmivora *chupon infection*

was arrested in mature tissues and some chupons with tip damage developed new growth from axillary buds on the mature stems.

Many isolated examples of the disease were found later in various places in Ghana, but it appears to be of rare occurrence and of only local importance. Collections of diseased leaves and chupons showing identical symptoms have been made from Umuahia in Nigeria, Isobi in the Southern Cameroons and from Portonos and Santa Isabel in Fernando Po. Distribution of leaf and stem infections in these countries is also sporadic.

ISOLATION AND REINFECTION

A *Phytophthora* sp. sporulated freely from diseased leaf and chupon material collected from the Mpraeso farm, after being kept overnight in humid chambers. The fungus was isolated easily on to oatmeal agar from stem tissue. Isolations from leaves were made by first implanting surface-sterilized diseased tissue into healthy cacao pods and then isolating from the lesions which subsequently developed in the husks. (Experience has shown that cacao pods are a highly selective medium for *P. palmivora.*) The *Phytophthora* was also seen to be freely sporulating from microtome sections of chupon material.

Zoospore suspensions of the isolates readily infected unhardened flush leaves when sprayed on to seedlings or on to detached flush leaves from mature trees kept in humid Petri dishes; the disease symptoms usually appeared within two days. The tip die-back symptom was reproduced by immersing the tips of seedling flush leaves in beakers of zoospore suspensions. Symptoms on seedlings were the same as previously described for seedling blight by Chant and Wharton; on newly formed leaves the pathogen spread rapidly down the main veins and the seedling was sometimes killed via the petiole. Under artificial conditions of constantly high humidity the leaves dehisced. On flush leaves which were beginning to harden the infection stopped once the leaves matured and did not always reach the stem. Stem infection was also blocked when the tissues hardened, although seedlings up to the second flush leaf stage were sometimes killed if infection destroyed the growing point and spread down to the cotyledon axillary buds before the stem hardened.

Further evidence that infection in mature tissue was arrested under natural conditions was provided by exposing seedlings of different ages on the Mpraeso farm. 240 germinating cacao beans contained in seed boxes placed at three sites were completely killed within ten days. Forty five young seedlings growing in baskets were also exposed and fifteen of these were killed. The remaining thirty were slightly more mature and their first leaves had hardened; they were severely injured, but survived.

There was no opportunity to reinfect plants with the isolates from Nigeria, Southern Cameroons and Fernando Po in their respective countries, to confirm their identities as original pathogens. Their symptoms were, however, identical with those of *Phytophthora*-infected material from Ghana, so the isolates were included in comparative tests to determine their identity.

IDENTITY OF THE PATHOGENS

Recent work at the West African Cocoa Research Institute, Ghana, has shown that the strain of *P. palmivora* attacking cacao pods in Ghana belongs to

the 'cacao' group of the species, and that the dominant pod-infecting strain in Nigeria, Southern Cameroons and Fernando Po is of the 'rubber' group (TURNER, 1960). Leaf and stem isolates from Ghana were compared with isolates from cacao pods and were found to be identical in the characters of development in cacao pods, sporangial dimensions and production of oospores with complementary strains. Also, the isolates could not be distinguished by differential response to polyphenolic additions to nutrient media, the method used by JARVIS (1957) to separate races of *P. infestans*. No difference could be detected between the cultures from Umuahia and Isobi and those from Ghana, and their characters agreed with the 'cacao' group of pod isolates. Fernando Po isolates were typical of the dominant 'rubber' group fungus attacking cacao pods there.

DISCUSSION

The results show that all types of damage to cacao caused by *P. palmivora* (pod rot, bark and cushion canker, seedling die-back and leaf and shoot damage on mature trees) occur in West Africa. As with pod infections, damage to vegetative tissues may originate from either of the two complementary strains of *P. palmivora* found in the region. Symptoms on pods can be a guide to the strain infecting them, but symptoms of these strains on leaves and shoots are identical.

The leaf stem infections have been found to be widespread in West Africa but are generally of only occasional occurrence. The exceptions are local outbreaks where conditions are extremely favourable for the development of *P. palmivora*; examples are the severe leaf and stem attack in the escarpment farm in Ghana, and the common leaf tip necrosis in the Tombel district of the Southern Cameroons. In the authors' opinion, the condition known as 'leafless twig disease' in the Southern Cameroons is unlikely to be caused by *P. palmivora*. Symptoms of leaf and chupon attack by this pathogen are characteristic and identical in all the cases examined, and bear no resemblance to those of 'leafless twig'.

SUMMARY

Leaf and stem infections of mature cacao trees in West Africa caused by *Phytophthora palmivora* (Butl.) Butl., are described and illustrated. The symptoms are characteristic and identical in Ghana, Nigeria, Southern Cameroons, Fernando Po and Cameroun, where the disease is widespread but of infrequent occurrence and of only local importance. Comparison of leaf and stem isolates from these territories showed that they are the same as the two complementary strains of *P. palmivora* found attacking cacao pods in West Africa.

All types of damage to cacao which are caused by *P. palmivora* in other continents are now known to occur in West Africa.

(*Received March 1960*)

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The Effects of Several Spray Régimes on Banana Fruit Weights

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Although Leaf Spot Disease, *Mycosphaerella musicola*, Leach, has been present in the Cameroons for more than a decade, only the conidial stages were observed up to 1954 when R. Leach first found typical ascospore symptoms. From 1954 onwards the disease spread rapidly and intensified to such an extent that control méasures were essential on the Cameroons Development Corporation's estates.

By early 1957 several thousand acres of bananas cultivated on level land were being sprayed with 3 lb of a proprietary brand of cuprous oxide in 9 gallons of water per acre by tractor-drawn ground machinery. By the middle of the same year arrangements were in hand for the rest of the acreage of bananas to be sprayed aerially with 2 gallons of fluid per acre. Initially the liquid was a mixture of oil and a proprietary formulation of copper oxychloride. All the bananas were the Gros Michel variety.

Improvements in application techniques followed, and by 1958 reliance was placed upon two methods of application. Tractor-drawn 'Giraffe' machines sprayed either 1 gallon of unadulterated oil or 2 gallons of water containing 2 lb of a cuprous oxide formulation per acre; and fixed-wing aircraft fitted with rotary atomizers sprayed 1 gallon of unadulterated oil per acre.

Nevertheless, fears were expressed in some quarters that formulations containing oil or even oil alone when sprayed on to the foliage of banana might be detrimental to fruit production. Many oils were screened by the Corporation in a search for an oil that was both cheap and comparatively low in terms of phytotoxicity. That fungitoxic differences existed between oils of broadly similar physical characteristics has been demonstrated [Price, D. (1958). *Trop. Agriculture, Trin.* **35,** 225] but the effect of spray oils on the banana plant could only be determined by long-term experiments.

EXPERIMENTS AND RESULTS

Early in 1958 three experiments were set up to determine whether or not oil affected the yield of the banana and one of these is described. The design used five randomized blocks containing five treatments on a site especially selected for uniformity of soil and uniform production of heavy fruit.

The records made were number of leaves and circumference at the date of shooting; stem weight, number of hands and fingers per stem, and number of functional leaves at harvesting. The fruit was harvested at full grade because this grade is the easiest to recognize in the field and errors are less likely to occur. The experiment was harvested weekly and these totals

combined to form quarterly results. The quarterly periods were selected to obtain maximum advantage of seasonal climatic differences thus:

March, April, May	Early rains
June, July, August	Rainy season
September, October, November	Late rains
December, January, February	Dry season

The five treatments are:

(*1*) 3 per cent water-based cuprous oxide at 40 litres per acre
(*2*) 60 per cent emulsion containing 250 g cuprous oxide at 10 litres per acre
(*3*) 60 per cent oil emulsion at 10 litres per acre
(*4*) 5 litres of oil containing 10 per cent v/v copper oxychloride per acre
(*5*) 5 litres of oil per acre.

The spray treatments were carried out fortnightly using a 75 cm^3 knapsack machine and Leaf Spot Disease was well controlled over the whole experiment.

At the end of the first year trends became apparent which suggested that all the treatments with oil reduced fruit weight in comparison with water-based copper fungicide. During the second year a severe storm damaged the experiment with the result that the bulk of the fruit was harvested during the dry period December 1959 to February 1960. Approximately 100 stems were harvested per treatment during this period. The mean fruit values for this dry season quarter are given in *Table 1*.

Table 1

Treatment	*1*	*2*	*3*	*4*	*5*
Stem weight (kg)	33·3	31·5	30·5	30·3	31·5
Hand weight (kg)	3·46	3·30	3·24	3·26	3·24
Finger weight (g)	194	186	182	180	182
Hands/stem	9·6	9·5	9·4	9·3	9·7
Fingers/hand	17·8	17·7	17·8	18·1	17·8

From these data it will be noted that whilst the number of fingers per hand is much the same in all treatments, the stem weights show some differences. This difference would appear, therefore, to be due to a difference in finger weight: a difference not inconsistent with an adverse treatment. The finger weights for the individual plots are given in *Table 2*.

The significant difference calculated on the pooled residual error at the level of one per cent is 37, and at 0·1 per cent 51.

Table 2. Mean plot finger weights (g)

Replication	*A*	*B*	*C*	*D*	*E*	*Total*	%
Treatment							
(1) *Water-based copper*	192	191	187	194	201	965	100
(2) *Emulsion+copper*	182	178	180	191	194	925	96
(3) *Emulsion*	180	182	172	192	185	911	94
(4) *Oil+copper*	174	175	178	182	189	898	93
(5) *Oil*	176	177	182	195	184	914	95
Total	904	903	899	954	953	4 613	

The mean number of leaves at shooting and harvesting with the consequent leaf loss are set out in *Table 3*.

Table 3

Treatment	*Leaves at shooting*	*Leaves at harvesting*	*Leaf loss*
(1) *Water-based copper*	13·4	4·7	8·6
(2) *Emulsion + copper*	13·7	4·9	8·7
(3) *Emulsion*	13·4	4·1	9·4
(4) *Oil + copper*	13·2	4·4	8·8
(5) *Oil*	13·8	4·1	9·7

There is no doubt that there was a sufficiency of leaves for good fruit development in all treatments. The fact that there were significant reductions in fruit weights and very little differences between numbers of leaves suggests that oil sprays reduce the efficiency of the leaves.

Because of the variability of the banana plant it might be suggested that the sample size of 100 stems is too small a size for analysis on which much reliance may be placed. To check on the reliability the finger weights for two years were analysed and the result is presented in *Table 4*.

Table 4. Mean finger weights from two years of harvesting

Treatment	*Mean weight (g)*	%	*No. stems/ treatment*
(1) *Water-based copper*	210	100	366
(2) *Emulsion + copper*	205	98	363
(3) *Emulsion*	199*	95	362
(4) *Oil + copper*	198*	94	274
(5) *Oil*	203	97	374

The significant difference calculated on the pooled residual error at the level of five per cent was 38 (based upon sum of 5 replicates).

WIND DAMAGE

During March 1959 a severe windstorm devastated more than a thousand acres of bananas amongst which this experiment was situated. A count was made of the number of 'break-necks' and uprooted bananas and these losses are give in *Table 5*.

Table 5. Losses from wind damage, March 1959

Replication	*A*	*B*	*C*	*D*	*E*	*Total*
Treatment						
(1) *Water-based copper*	40	42	38	41	27	188
(2) *Emulsion + copper*	39	45	43	45	47	219*
(3) *Emulsion*	46	42	47	39	33	207
(4) *Oil + copper*	48	46	36	52	36	218*
(5) *Oil*	41	28	47	32	43	191
Total	214	203	211	209	182	1 019

A chi-squared test showed that the emulsion + copper and oil + copper treatments lost significantly more plants than the water-based copper treatment, which suggested that these oil-sprayed plants were less wind resistant.

CONCLUSIONS

There can be little doubt from the results of this experiment that the use of oil as a fungistat adversely affects the development and growth of the banana. The oil used for these treatments was considerably more refined than others freely available during 1957 and had an unsulphonated mineral residue of 96 per cent. It might be concluded from these results that all oils will be toxic to the banana plant to a greater or lesser extent. The choice facing the banana grower is whether to accept this loss of revenue and hope that it is not cumulative or to switch over to water-based copper spraying or to use a combination of both methods.

At present most control methods rely upon spraying a deposit of a fungicide or fungistat on to the upper leaf surfaces. In those countries where the ascospore damage represents a threat to production the use of a water-based copper fungicide may not give adequate control because of a slow but steady build-up of ascospore infection. The substitution of oil for copper fungicide will remove this danger but introduces the problem of reduced fruit weights and wind resistance.

In the Cameroons the climatic seasons are well defined as will be seen from the sunshine and rainfall data for Ekona Research Laboratory (*Table 6*).

Table 6

Period	*Rainfall in.*	*Rainy days*	*Sunshine h*
Mar–May 1959	21·78	43	395
Jun–Aug 1959	45·20	73	117
Sep–Nov 1959	18·98	54	280
Dec–Feb 1960	2·39	2	409

Most of the fruit in the Southern Cameroons is shot during and after the rains and is harvested during the dry season. The rain during August is so intense that Leaf Spot Disease is virtually dormant; alternate wetting and drying of old leaves, necessary conditions for ascospore discharge, does not occur, whilst conidia are washed off the leaf before maturity. This respite from active disease control methods is of great value because it permits the use of oil during the early rains when little fruit is shot, and which would reduce the development of ascospore infection and subsequent formation of perithecia. As a result of this oil spraying and short period of no spraying a water-based copper fungicide may be used after the rains with considerable confidence that ascospore infection will be slight and that the developing fruit will attain a normal and not reduced weight.

SUMMARY

Some results of a long term experiment, which is continuing, to determine the effects of spray oil on fruit weight are given. These show that the use of oil to combat Leaf Spot Disease, even in small dosages, leads to a reduced fruit weight which may be enhanced by dry sunny climatic conditions.

(*Received March 1960*)

Book Reviews

AN INTRODUCTION TO ANIMAL HUSBANDRY IN THE TROPICS

G. Williamson and W. J. A. Payne. Longmans, Green: London, 1959. *xix* + 435 *pp.* (illus.) 48*s*

An authoritative textbook on animal husbandry in the tropics is long overdue, and this publication will be widely welcomed by all teachers of tropical animal husbandry.

The book is in a sense, a pioneer venture and therefore the task confronting the authors is extremely difficult whilst that confronting the reviewer is comparatively simple. There is much to criticize in the first edition of this textbook but little that cannot be put right in later editions, with the result that eventually a most worthwhile textbook will be available.

The first serious criticism is that the style of writing varies so considerably between chapters, presumably as a result of the dual authorship. Most of the important reviewing of scientific advances, as distinct from mere hearsay, appears in the chapters on 'Effect of climate' and 'Cattle', whilst the chapters on 'Maintenance of health', 'Buffalo', 'Camels' and small stock detract from the value of the work as a whole. The former chapters have an easy style with short, simple sentences which make good reading. The style in the latter chapters is extremely verbose and the chapters say little from the point of view of a critical appraisal of factual information. For instance, on pages 20 and 21 in the chapter on 'Maintenance of health', a sentence appears consisting of 133 words divided by 3 commas, 1 semicolon, 3 colons and a dash! Again the writer frequently puts up Aunt Sallies merely for the enjoyment of knocking them down. For instance, on page 21 we read the following statement of the obvious, 'the ordinary stock owner cannot expect to be an expert in veterinary science nor is it necessary that he should be . . .' Again, at times the author forgets the purpose of the textbook as given in the foreword, and writes in a style appropriate for students below farm institute calibre. Thus on page 28 we read: 'The infected animal is a nursery for the germs and diseases which it cultivates and passes to all and sundry'. This may be good enough for a book of elementary biology; it is certainly not good enough for the university undergraduate in tropical agriculture.

A serious omission in this book is that it contains no information whatsoever on horsekind, although horses, mules and donkeys are important as draught animals in many different parts of the tropics. Whereas farm horses are usually dealt with in textbooks of temperate animal husbandry, little or no treatment is given to donkeys and mules. This serious deficiency needs to be rectified in later editions of any textbook on tropical animal husbandry.

A few of the references need correction. For instance, the paper on Zebu cattle by S. B. Kikule is wrongly attributed to Kibule in both the

text and the references. Again in the chapter on the buffalo, the article (or book?) attributed to KARTHA, K. P. R. (1943) is not adequately referenced according to accepted practice. Yet again, the Awasi (or Awassi?) breed of sheep is spelt two ways, one in the text and the other in the references (p 279).

At times the authors are a little too dogmatic in their statements and it is apparent that the book has been prepared in manuscript a fair time before appearing in print. The result is that no allowance has been made for research work conducted and published since the text was written, and certain of the dogmatic statements now require qualification. For instance, the authors are incorrect in assuming no published grazing behaviour studies have been conducted on the smaller livestock. The East African dwarf goat has been studied and reported in some detail, in the same region where Dr PAYNE is now working!

Another example is given, on page 174, where it is stated that the oestrus periods of Zebu cattle are shorter than those of European breeds. This has been disproved by ROLLINSON who has shown, as long ago as 1955, that the length of oestrus is almost identical, and it is merely the external signs of oestrus which differ. Again in the chapter on sheep (p 271) it is stated that hand feeding of ewes is only economically important when applied to improved breeds or their crosses in climates to which they are adapted. Recent work with Black Head Persian sheep has shown a marked and economic response of the ewe and lamb to steaming up and limited concentrate feeding during early lactation. Even greater criticism can be levelled against the statement on page 305, that ' piglet anaemia . . . is not seen '. The work conducted in the tropics on blood haemoglobin levels, and growth responses to intramuscular injection of iron, indicates that the converse is true.

The best, and by far the longest, chapter in the book is the one concerning cattle. The worst chapters are those concerning small stock which deserve much fuller and more scientific treatment. For instance, the chapter on camels is fragmentary in the extreme and gives merely four references, of which only one is a scientific paper. Many elementary mistakes occur in this chapter; for instance the scientific name of the camel is not correctly given and the author confuses families with genera. The chapter on sheep completely omits descriptions of husbandry practices peculiar to this class of stock, for instance, shearing, dipping, worming, tail docking, hoof trimming, etc. The appropriate husbandry practices are fully described for cattle, and similar treatment should be given to all classes of the smaller livestock.

The book is well illustrated in respect to cattle, and to a lesser extent with respect to sheep and pigs. There are no adequate illustrations concerning the other small stock. This deficiency could be corrected in later editions.

To sum up, about three quarters of this book makes excellent reading and fulfils the task of providing a much needed textbook for students of the subject. It is regretted that the other quarter has not reached the required standard—T.R.H. and P.N.W.

AGRICULTURE AND ECOLOGY IN AFRICA

A Study of Actual and Potential Development South of the Sahara
J. PHILLIPS. Faber and Faber: London, 1959. 423 *pp.* (illus.) 63*s*

There can be no doubt that a major cause of the lack of success of many projects for agricultural development in Africa has been a failure to study and appreciate the ecological background which so largely determines the agricultural potential of an area—the crops and livestock which can be economically produced, and agricultural practices and methods which need to be adopted. Professor PHILLIPS is acutely aware of the great waste of money and effort which have attended this failure and of the need for agricultural development to take place on an ecological basis. In the first three parts of this book he has endeavoured to classify and describe the various bioclimatic regions and sub-regions of the continent south of the Sahara and to give an account of their potential and problems for agricultural and related development. To discharge this task thoroughly and in detail, which would amount to providing a comprehensive guide to the ecology and agricultural potential of the many and varied regions of a vast continent is, of course, impossible because of the meagre information on climate; soils and vegetation as yet available for much of Africa. Professor PHILLIPS is naturally well aware of this and even goes so far as to refer to his account of ' the great wooded savanna and related bioclimatic regions ' as ' necessarily sketchy and uneven '. This is a correct assessment, but nevertheless he has gathered together a tremendous amount of useful information.

Unfortunately, however, the value of this information to the reader is reduced by three circumstances. In the first place the style of writing is flowery and involved which, apart from being slightly irritating, often makes it a little difficult to understand what is meant without re-reading. There are some places in the book where the style, possibly coupled with faulty proof correction, results in sentences which seem quite meaningless, as, for example, on page 137: ' Provided for these, the podsolic soils carrying forest and the intrazonal hydromorphic or ground-water laterite are details of climate, vegetation, relief, parent materials, colour, texture, structure and potential productivity '.

Secondly, in this and the other parts of the book, a number of statements occur which are either partly or wholly incorrect. For example, it is stated that in forest areas extensive and maintained clearing of woody growth higher up a slope ' frequently induces an accumulation of moisture in the soils lower down, with consequent deterioration in drainage and erosion—deleterious to all but water-demanding plants such as swamp rice and jute '. This, however, could only occur very infrequently or temporarily under rather special circumstances. Another example is the statement, several times repeated, that a problem of annual cropping of forest soils is loss of phosphate by leaching, whereas available evidence indicates that this nutrient is not lost in this manner.

Thirdly, and much more important, the method of classifying and describing the various ecological units and their agricultural potential does not make for clarity. Division is made into: (*a*) the forest bioclimatic region

and (*b*) the wooded savanna and related bioclimatic regions. The bioclimatic region, or panclimax, is defined as being ' [illegible] terized by broad climatic, physiognomic, structural and biotic si [illegible] and common promise for agricultural development '. In fact [illegible] ver, zones with completely different climatic conditions and agricultural potential are included in the same bioclimatic region, as may be seen from the fact that the forest bioclimatic region includes the highly humid, hot, lowland forest of the Congo, the humid montane forests of the highlands of Kenya, and the sub-tropical, humid to sub-humid, lowland–midland forest areas of Knysna and the southwest Cape. It is true that the diverse types so included in the forest bioclimatic region are dealt with individually in Chapters 7 to 10, where the region is divided into divisions, sub-regions and units, and some information is given for each unit on its geographical extent, altitude and vegetation. The main account of the climatic factors, soils and agricultural possibilities is, however, given for the bioclimatic region as a whole in Chapters 11 to 15 and although some attempt is made to indicate variations in these factors between different sub-regions and units, the result is a somewhat confused picture.

The wooded savanna bioclimatic region is divided into five sub-regions, namely, the sub-humid, the mild sub-arid, the sub-arid, the arid and the sub-desert. Each of these is subdivided into areas north of the equator, south of the equator, or subtropical, and under each of these subheadings different variants are described by reference to their approximate geographical location. The resulting account suffers from several unsatisfactory features. First, some of the units described include at least two zones of quite different climatic conditions, vegetation and agricultural possibilities. This is so, for example, for the variant of the sub-humid wooded savanna, south, described under the heading of ' Parts of the Lake and the Western Provinces and of the Southern Highlands, Tanganyika and parts of Kenya ', which includes typical *Pseudoberlinia–Brachystegia* woodland in the Tanganyika section and the quite distinct *Combretum–Hyparrhenia* woodland or savanna at much higher altitudes, and under appreciably higher rainfall, in the Kenya section. Secondly, a number of the units separately described actually possess the same or very similar vegetation and climate as, for example, the several units in which the vegetation is described as *Pseudoberlinia–Brachystegia.* Thirdly, there are considerable areas which, although demarcated on the map, are not mentioned in the text, for example, much of Uganda and the greater part of Nyasaland. It is difficult to resist the conclusion that it would have been more satisfactory to have adopted a broader, simpler classification and to have dealt with all aspects of each subdivision under one heading. In this connection it is perhaps unfortunate that the classification adopted by KEAY *et al.* in *Vegetation Map of Africa 1959* was not available until the later stages of the preparation of this book.

In the fourth part of the book other important matters re[illegible]ted to agricultural progress are discussed, such as the problems of human and animal health and nutrition, of lack of water and lines of communication, of sociological change, of the low to marginal economy in the agriculture of many parts of the continent, and of providing adequate basic information,

planning, organization and management for development. There is a good comparativ[illegible]sis of the Gezira, the Groundnut Scheme and the Volta Project a[illegible]able chapter which examines the factors making for success or fai[illegible] major agricultural development schemes.

In the first chapter of Part Five Professor PHILLIPS reviews the sins of omission and commission of those responsible for the administration of Africa and then, in the last two chapters, sums up the present situation and makes proposals for greater and sounder development in the future. This part of the book contains much which is of value and wise, but the highly critical first chapter lays too much stress on the failures of European administrators and technicians and not enough on the great difficulties with which they have been confronted. Criticism of the efforts of Europeans in all the technical fields discussed is justified, but that levelled in Chapter 24 is frequently too severe and a balanced statement of all the major facts is not always presented, although some of these facts are brought to light later in the book. For example, it is stated that ' in the settling and opening up of parts of the continent soil and water resources have been despoiled and even ruined ', and that ' conservation farming has not been applied in Africa, except very locally '. This is true, but unfortunately the impression is given that the European is largely to blame for this and it is stated that ' on the mass of European properties conservation farming is still a common act of omission '. In fact, although despoliation of resources has occurred, and to a more limited extent still does occur, on some European properties, its extent is quite negligible in comparison with the huge areas where serious deterioration has resulted from bad land use by African farmers who, despite the long-continued efforts of agricultural extension workers, have not appreciated the need for conservation farming and are continuing to spoil land on a vast scale. In this the Europeans can only be blamed in that they have failed to devise extension methods which would convince the Africans and stimulate in them the effort needed for conservation farming.

To give one more example, after referring to the fact that ' tsetse and trypanosomiasis lock away much of tropical and equatorial Africa for man and domesticated beast ' it is stated that ' governments consistently have omitted to apply the requisite practices of tsetse control. Moreover they have neither provided water and other facilities—domestic and agricultural —for settlers nor regulated livestock numbers according to the natural vegetation and the water supplies '. In fact, governments have eliminated tsetse from, and provided water supplies for, very considerable areas, but, despite long-continued efforts, have failed to persuade Africans to cooperate in limiting stock numbers to carrying capacity and in improving their methods of land use and animal husbandry. In these circumstances elimination of the fly and provision of water merely enable Africans to keep still larger numbers of unproductive stock and to ruin yet more land. Professor PHILLIPS is, of course, well aware of this and also that the crux of the whole problem is to persuade African pastoralists to abandon their age-old custom of keeping as many cattle as possible, mainly as a matter of prestige or for use as bride price, and to develop a commercial attitude and raise stock for sale and profit. Unfortunately, however, these points are not mentioned until later in the book and in a different context. It might be added that,

even given improved livestock, good land use and good animal husbandry, the return from investment in tsetse control and water supplies is likely to be low, and even marginal, because of the inherent low potential of much of the tsetse-infested areas.

Bringing together as it does a great deal of useful information from a variety of sources, and containing many sound comments and proposals for the future, the book should be read with profit by those with some experience and knowledge of agriculture in Africa, but to those lacking such knowledge parts of it may prove confusing or misleading—C.C.W.

EFFICIENT USE OF FERTILIZERS

V. Ignatieff and H. J. Page. Revised and enlarged edition. *F.A.O. Agricultural Studies No. 43.* United Nations Food and Agriculture Organisation: Rome; Her Majesty's Stationery Office: London, 1958. *xxi*+ 355 *pp.* (illus.) 22*s* 6*d*

No. 43 in F.A.O.'s series *Agricultural Studies* is basically a revised edition of *No. 9* published in Washington in 1949.

This manual has been written for a wide audience, including extension workers, farmers and students, on a world-wide basis. It is not an exhaustive treatise, nor a detailed practical handbook. The two editors, both distinguished in the field of tropical plant nutrition, have distilled the views of nearly 100 authors. In spite of inevitable generalization, however, it contains sufficient information for the diligent reader to adapt principles to his particular requirement.

Chapter 1 introduces the subject. World consumption of fertilizers has doubled to over 20 million tons since the earlier edition of the title. Crop growth factors are briefly mentioned under 10 points—these might with advantage have been expanded. The importance of planning farm usage of fertilizers is rightly stressed but ' dry soils need irrigation ' and ' on acid soils, liming is usually necessary ' need qualifying for many tropical crop conditions. The enormous impact of soil deterioration processes is briefly mentioned in a short section emphasizing the importance of sustained production in agriculture.

Chapter 2 sets and maintains a suitably high standard of formal discussion on the various plant nutrients, their sources, availability, deficiencies and toxic effects and concludes with brief mention of imbalance in animals. The frontispiece, presumably wrongly referred to on page 22 as Figure 3, showing four deficiency symptoms in maize, is not as good as that of the earlier edition (which, however, suffered from display against a poorly chosen background).

Chapter 3 provides a substantial and comprehensive treatment of organic matter with particular reference to the making of composts, disposal of towns' refuse and sewage. Whilst the importance of organic matter as a seat of microbial activity and as a physical soil improver is readily admitted, no attempt is made to join issue with the organic husbandryman on the subject of crop health.

Chapter 4 is a potted textbook in itself on fertilizers as such and deals with source, manufacturing processes, various types of classification, grades,

mixtures and finally briefly with the liming, anti-alkali and aggregating amendments. This is an excellent chapter insofar as a brief but full survey of a very wide field is required. The section on probable developments is particularly interesting. In this we see that as far as nitrogen is concerned, the synthetic ammonia process of production is supreme and that a new class of high analysis, slow release compounds derived from urea and formaldehyde show great promise; the use of high analysis phosphates, dependent upon enrichment of lower grade fertilizers by phosphorus and nitric acids, will expand; more use will be made of trace element additions and ' glasses ' for slow release together with organic chelates which tend to reduce soil fixation. There is little prospect for further development of the already naturally high analysis potassium compounds apart from increased usage. The section dealing with grades and ratios might with advantage have been expanded by a footnote defining unit cost and detailing examples of calculation of quantities for mixtures. A noticeable omission is reference to the extensive Russian utilization of bacterial fertilizers.

Chapter 5 approaches the title and discusses factors concerned with efficient use of fertilizer in terms of soil, climate and crop and of the characteristics of the major and some minor elements themselves. Many examples of practice are given, but tend to be in such general terms, e.g. ' In the United States, Canada and United Kingdom . . .' as to lose their point. The section on nitrogen is placed after that on potassium instead of in the commonly accepted nitrogen–phosphorus–potassium sequence.

Chapter 6 emphasizes three cardinal points of fertilization, i.e. the right kind, at the right time in the right way. The respective merits of broadcasting and placement are adequately covered, as is the standard problem of dealing with liquid and solid organic manure. The lime and pH story is then briefly dealt with. There is no treatment of how to apply fertilizer to perennial tree crops in the tropics.

Chapter 7 enlarges on the accepted view that in properly planned rotational farming one of the benefits is that more efficient use can be made of fertilizers, and gives examples of current rotation from several temperate areas. The tropics receive attention in the form of descriptions of monoculture and shifting cultivation. In the section on green manure and cover crops the reader waits in vain for any mention of the use of fertilizers to grow them.

Chapter 8 discusses the major soil groups of the world and briefly mentions their major nutrient deficiencies. The tendency here is to look upon fertilizers as the only necessary ameliorant. In practice, however, the extensive use of mechanization has probably been more effective in raising world food production.

Chapter 9 deals with crops and fertilizers. A total of 32 crops is covered, the only notable omission being the cordage fibres. The treatment tends to generalize and discuss the growing conditions. Cocoa, for example, is given two and a half pages without any indication whatsoever of quantity or proportion of fertilizer to use.

Chapter 10 discusses the economics of fertilizing and makes the point that few other purchased factors contribute so much to output and income. Machinery is dismissed as a mere labour-saving device; this does less than

justice to the essential position held by powerful machinery capable of carrying out deep cultivation under dry conditions in West Indies sugar production, for example. Government assistance in the form of subsidy, credit provision and education of farmers into the economics of fertilizer use are topics that lead into Chapter 11. Here the authors recommend basing efficient fertilizer use programmes on average crop responses, on the same soil in the same district, obtained from a large number of field experiments. This recalls war-time England when the most efficient use of fertilizer in short supply had to be based on ' which crop first and how much '. The importance of field trials on representative soil types is emphasized and the plea is made for more simple experiments on farmers' fields. The value of extension work in obtaining efficient fertilizer use is not overlooked and the final section discusses, rather cursorily, research and advisory services in a number of countries.

The book is well written in a pleasing, uniform style. It is provided with a good index and a bibliography of some 500 entries grouped according to chapter requirements.

A standard list of conversion factors from metric to British and American equivalents is included; this does not, however, contain a definition of quintal (a tenth of a metric ton) used in one of the text tables.

The main criticism offered here is on the length of the work; in these days of verbal bombardment the only excuse for increase of pages is corresponding increase in relevant fact. This new study, interesting and well written though it is, has not doubled its value by doubling its size.—R.H.F.

THE MEASUREMENT OF GRASSLAND PRODUCTIVITY

Proceedings of the University of Nottingham Sixth Easter School in Agricultural Science, 1959

Edited by J. D. Ivins. Butterworths: London; Academic Press: New York, 1959. *viii*+217 *pp.* 35*s* or $7.00

The editor and publishers of this excellent publication must be congratulated on the speed with which the proceedings of a conference held in mid-April 1959 have appeared in book form before the end of the same year, in spite of the difficulties of the prolonged British printing strike.

The Easter Schools in Agricultural Science held at the University of Nottingham School of Agriculture provide a very useful forum for the exchange of ideas in one particular branch of agricultural research. It is a great tribute to the organizer of these Easter Schools that papers of the standard of those appearing in this book are presented at this particular forum. It is inevitable that papers will differ in quality and it would only be invidious for the editor to have to select some whilst omitting others. However, the reviewer must point out that certain sections of this work, such as the contribution made by Professor Klapp of Germany, are very much inferior in quality to other sections, for example, the section on ' The value of herbage estimates in animal production experiments ', contributed by Mr Line.

The book is divided into five parts, one concerned with general aspects of the measurements of grass and productivity, the second concerned with herbage growth, the third with the consumption of herbage by livestock, the fourth with animal production from grassland and the fifth with farm-scale measurements. Parts 2 to 4 inclusive provide a great deal of critically analysed factual information, and must be considered essential reading for any research worker engaged in this field. Parts 1 and 5 may give a useful beginning and ending to the book, but they deal with matters of a very general nature which do not present any new facts or new ideas.

One important theme which runs throughout the whole of this publication is the major importance which workers should attach to better definitions of grazing systems, grass growth measurements and animal response data. The point is well made by Mr ALDER in the section on ' Pasture experiments with animals ' in which he states that the arguments concerning the relative merits of different grazing methods arise largely through lack of definition of terms and of requirements. This book points out that agronomists still fail to give adequate definition of the exact method employed in cutting treatments used in obtaining grass production data. Even a simple statistic such as the dry matter content of the grass requires to be carefully defined, as the diurnal variation in dry matter, quite apart from the day to day variation in dry matter, is often quite appreciable. The terms ' rotational grazing ', ' strip grazing ', ' high and low rotation speed ', ' high and low stocking rate ', are not self-explanatory and need most careful detailed definition both in the planning of treatments in a given experiment and in the interpretation of the experimental results.

If this book serves the purpose of persuading research workers to follow the well-known precept of the late Dr C. E. M. JOAD, and preface their arguments by the phrase ' It depends on what you mean by . . .' a great service will be done to applied agricultural research in grassland husbandry. —P.N.W.

NIGERIA'S FEEDING-STUFFS

Their Composition and Nutritive Value

V. A. OYENUGA. 2nd ed. Ibadan University Press: Ibadan, 1959. 65 pp. 8*s* 6*d*

This publication is the second edition of a small paper-backed booklet on some analyses and qualitative descriptions of certain of the feeding stuffs commonly used for livestock in Nigeria. The publication serves a most useful purpose, but a few points might be considered in any further modification of it for a third edition.

In particular, the references provided at the back of the booklet are not presented in orthodox form. The abbreviations of scientific journals do not follow accepted practice as laid down by the *World List of Scientific Periodicals*, and there is a lack of uniformity in the provision of first and/or last page numbers of papers cited. The book is written in easy style, but at times the colloquial method of expression gives rise to examples of bad sentence construction. Thus, on page 8, there is an example of a double negative in the sentence ' it is not incorrect to state that . . . do not live on an adequate plane of nutrition '.

The author makes the point that the samples on which the chemical analyses were taken were derived from northwest Nigeria, and that other samples taken from north Nigeria may differ in composition. However, in the calculation of the values in digestible nutrients, digestibility coefficients are taken from the works of MORRISON and SCHNEIDER, both these publications being by American authors and using data applicable to American material. The analyses presented would be far more valuable if backed by digestibility coefficients obtained at the University College, Ibadan. If it is argued that the data provided are the best that can be presented at this stage and that this publication should not await the conduct of local digestibility experiments, then there are most certainly no grounds for producing tables of total digestible nutrients with the accuracy of two places of decimals!

Fuller details of the exact stage at which the feeding stuffs were harvested for analysis will greatly assist the reader of this publication. Thus the analysis of ' sugar-cane leaves ' does not mean very much unless it is clear whether the cane leaves were harvested during normal cane harvest (i.e. at full maturity) or whether they were harvested from young growing plants at an early stage of development.

In spite of the foregoing criticisms, the book is a most useful publication and it is hoped that its production will stimulate other animal nutrition chemists in other parts of the tropics to publish data derived from their local materials. Only in this way will the full range of variability in the quality of tropical feeding stuffs be ascertained.—P.N.W.

AFRICAN AGRICULTURE IN NYASALAND

Nyasaland Department of Agriculture: Zomba, 1959. 267+xiv *pp.* (illus.)

It is difficult and perhaps a little pointless to attempt to review critically a book that has been compiled by a department for distribution and use among its own ranks, but it would be a pity not to notice such a worthy effort as this. This textbook, published by the Nyasaland Department of Agriculture, is intended primarily for its African Instructors and aims, in the words of the preface, ' to provide them with a source of increased knowledge and a means of refreshing their minds in the technical aspects of their work '. It will not be the fault of the compilers if this aim is not achieved. In simplified textbooks of this kind it is so often a question of what to leave out, but a comprehensive coverage of a diversified agriculture is achieved here without the inclusion of academic detail, and a direct and lucid style is maintained throughout.

The text has been cyclostyled on foolscap paper from a typescript and one might have expected, therefore, that illustrations would be few because of the difficulties of reproduction. On the contrary, all chapters are amply illustrated not only with clear line drawings but also with photographs the reproduction of which is, on the whole, exceptionally good. In the copy under reference, there is only one photograph (Fig. 45) that does not adequately illustrate what the caption states it should. One or two drawings are inverted in relation to their captions, but these are minor defects that can easily be corrected in subsequent editions. Although it is intended in the main for use by African Instructors, one may safely prophesy that

there will be few Agricultural Officers in Nyasaland who will not find this book extremely useful during the early part of their careers. Broad side-margins will enable them to supplement the text with their own notes and they will find the appendices particularly valuable. The first of these lists, and briefly describes with English and vernacular names, some of the commoner weeds; the second provides a selection of frequently used weights, measures and approximations.—M.H.B.

Recent Publications

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A Notebook of Tropical Agriculture. 6th ed. rev. and enl. 1957. 12*s* 6*d*

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No. 6 British Guiana. The Rupununi Savannas (continued). The Intermediate Savannas. General Remarks. 1959, 15*s*

No. 7 Jamaica. Parish of Clarendon 1959, 20*s*

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No. 9 Grenada. 1959, 18*s*

No. 10 Jamaica, Parish of St Mary 1960, 14*s*

These and earlier publications can be obtained from the Library and Publications Department, Imperial College of Tropical Agriculture, Trinidad

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The following books written by members of the staff have recently been published:

Insect Life in the Tropics, by T. W. Kirkpatrick. Longmans, Green: London. 35*s*

Bananas, by N. W. Simmonds. Longmans, Green: London. 45*s*

CONTROL OF THE PLANT ENVIRONMENT

Proceedings of the Fourth Easter School in Agricultural Science, Nottingham, 1957

Editor: J. P. HUDSON

Control of various factors of the plant environment offers a powerful new research tool for the study of growth and yield. This approach offers attractive opportunities in fields of research ranging from fundamental aspects of plant physiology and genetics, to applications of immediate importance in plant breeding, agriculture and horticulture.

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GROWTH OF LEAVES

Proceedings of the Third Easter School in Agricultural Science, Nottingham, 1956

Editor: F. L. MILTHORPE

All aspects of agricultural production are intimately associated with the growth of leaves, and the yield ultimately depends on the rate of addition of dry matter per unit area of land, i.e. on the efficiency of the photosynthetic processes and on the extent of the photosynthetic surface.

Agricultural writings, however, reveal much confusion as to the relevant importance of these two components of energy production with, consequently, much misdirected effort in plant breeding, fertilizer and other agronomic programmes. The 1956 School provided a forum for discussion among specialists in leaf growth. Research workers and honours students in botany, agriculture and horticulture will find much of interest in these papers. Constant reference has been made to source material and, with diligent use, this volume will assist the reader to obtain a full understanding of leaf growth. Price 40s.

QUANTITATIVE PLANT ECOLOGY

By P. GREIG-SMITH, M.A.
University College of North Wales

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—*Agricultural Institute Review*

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